metal treatment and Drop Forging

Vol. 25 : No. 156 SEPTEMBER, 1958 Price 2/6

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The problem

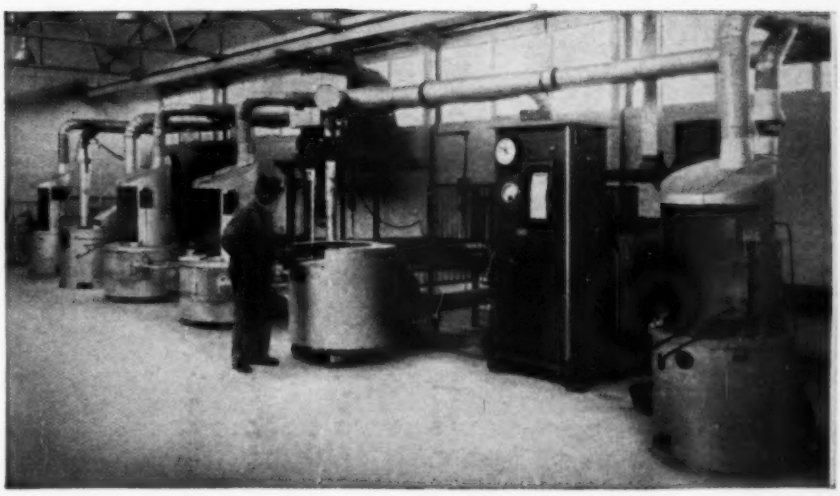
set by
ALDRIDGE TOOL AND ENGINEERING CO. LTD.

To heat treat large numbers of different kinds of high-speed steel tools, with minimum distortion and no decarburisation, to ensure long life in use.

the answer

given by the 'Cassel' Heat Treatment Service

After suitable preheating in air and then in a 'Cassel' P.S.760 salt bath, the tools are transferred to the high temperature 'Cassel' H.S.970 bath, in which they are soaked for the required time, and then quenched in a 'Cassel' Q.S.540 bath and finally air cooled. Secondary hardening treatments are also carried out in Q.S.540. The 'Cassel' furnaces and salts provide the most convenient and speedy method for obtaining optimum results.



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IMPERIAL CHEMICAL INDUSTRIES LTD., LONDON, S.W.1

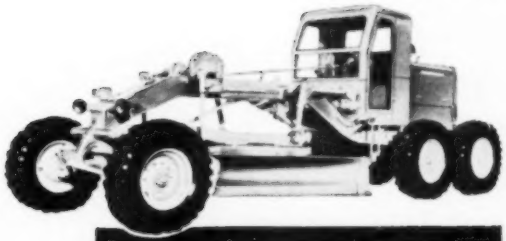
CC.186

They rely on

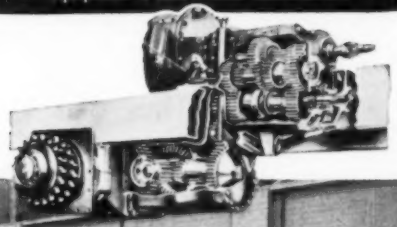
WILD BARFIELD

Gas Carburising at

Blaw Knox Ltd.



Gears and main driving shafts for the BK-"Super-12" Motor Grader have to stand up to exceptionally tough working conditions. Wild-Barfield gas carburising equipment is used in their manufacture.



Wild-Barfield "P.T.G." Gas Carburising installation at Blaw Knox Ltd.

Precise control of depth and type of case is afforded by both Wild-Barfield gas carburising processes—the "P.T.G." and "Carbodrip" drip feed. By these methods carburising proceeds at almost the maximum theoretical rate. We will be glad to send you full details on request.

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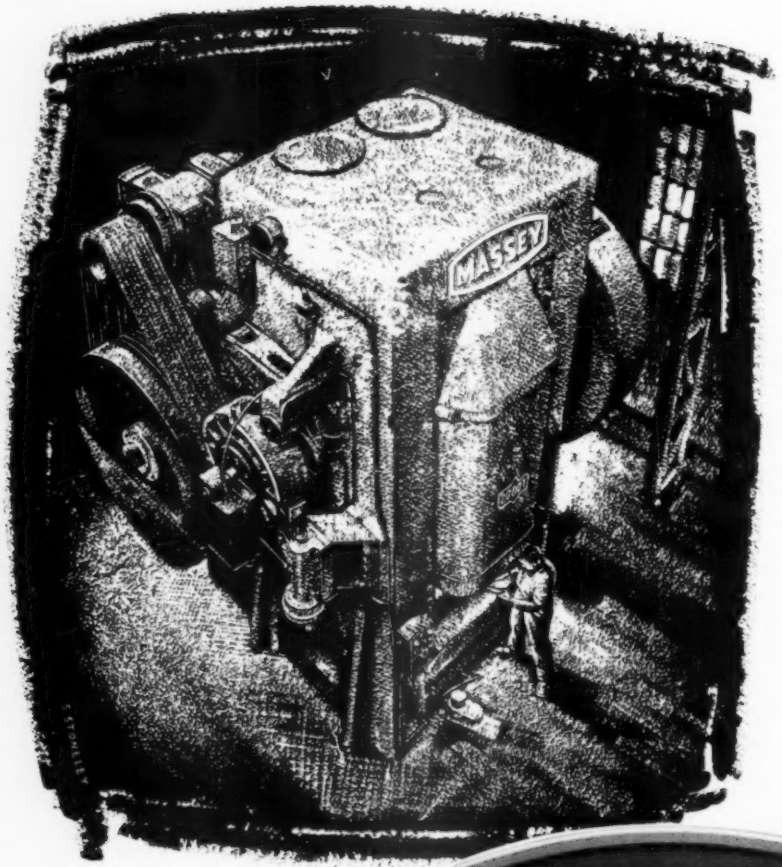

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Massey forging presses can be used for three distinct purposes—die forging, extrusion and coining. They are simple to operate, enabling unskilled labour to be employed; and practically, output is limited only by the material handling facilities provided. High Speed Presses are available in sizes from 300- to 3,000-ton and the Low Speed Presses from 300- to 1,000-ton.

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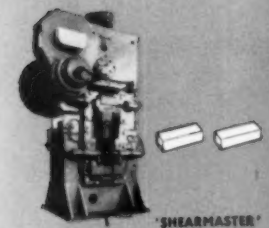
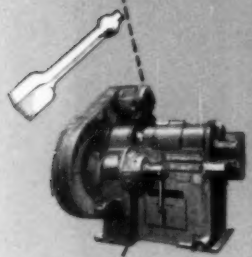
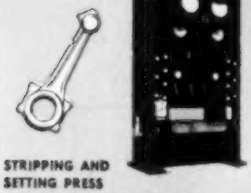


'SHEARMASTER' BILLET SHEAR



'ROLLMASTER' FORGING ROLLS

'FORGEMASTER' HIGH SPEED FORGING PRESS



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600 ton capacity Stripping and Setting Presses in the Works of Messrs. Clydesdale Stamping Co. Ltd., Netherton.

Wilkins & Mitchell Forgemaster High Speed Forging Press, 1,500 tons capacity, and Clipping and Setting Press in production on precision forgings for Messrs. Garringtons, Bromsgrove.

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TELEPHONE : KIVETON 252 (3 LINES)

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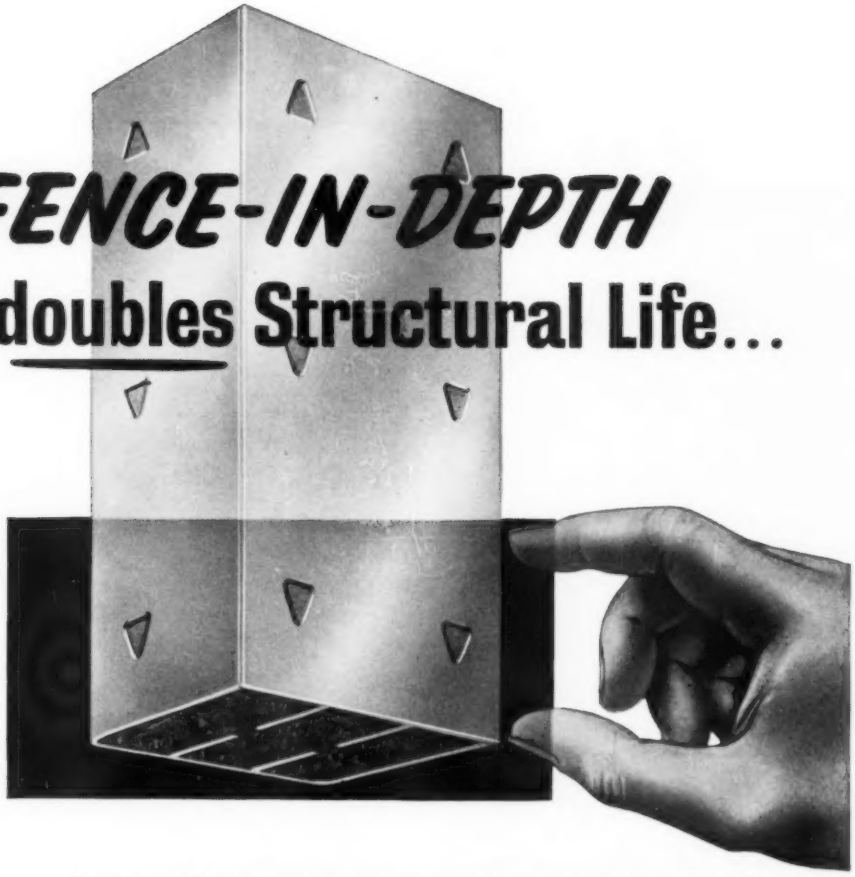
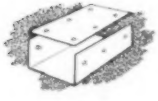


Specify 'GR' FERROCLAD 'EE'



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Technical advice and assistance on the selection and application of Refractories are always available on request.

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Heat treatment furnaces with special features

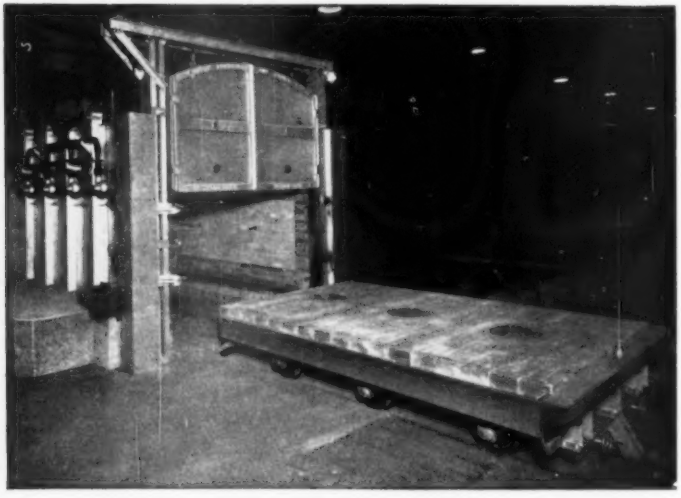

Photo by courtesy of
Messrs. Lloyds (Burton) Limited

"Fulload" furnaces offer . . .

Maximum efficiency with minimum fuel consumption. The unique exhaust flue arrangement in the bogie hearth ensures speedy heating of the load, constant temperature in the furnace and the elimination of cold areas in the heating zone. We supply furnaces for all purposes and all fuels, batch type or continuous.

For further particulars ask for leaflet 47.

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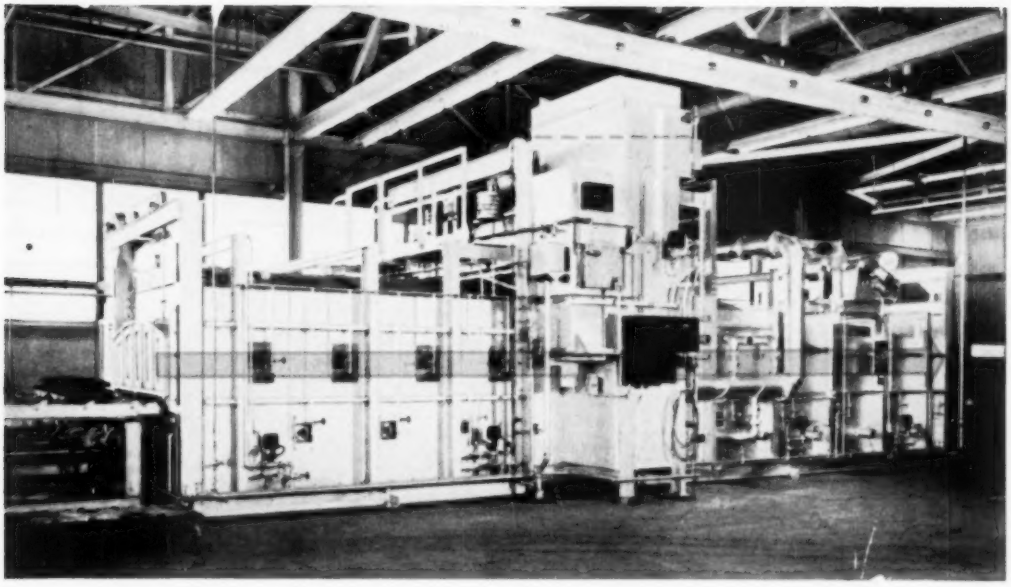
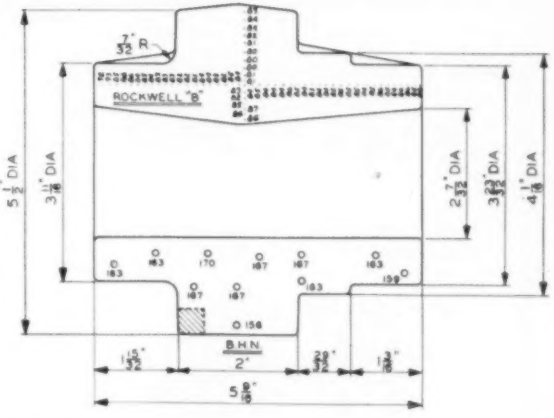
Superfast cooling for cycle annealing



A furnace-within-a-furnace makes this cycle annealer one of the most versatile heat treat units in the country. It anneals, cycle anneals, and normalizes gear forgings of different size, shape, and alloy at the net rate of 1,250 lbs. per hour, or better.

Such exceptional versatility is achieved by a superfast cooling zone. Really a full convection furnace within a direct-fired furnace, this zone is isolated by refractory doors. It can be used or by-passed, depending on which of many cycles the customer wants. As a result, the customer can heat treat as many as 13 different alloys in this one furnace.



Adding to the flexibility of the furnace is a modular tray design. Each module is an 18 × 20-inch chrome alloy casting. Modules can be combined to hold any size of work up to 800 pounds. They are also used to carry work outside the furnace.

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ASSOCIATED WITH SURFACE COMBUSTION CORP., TOLEDO, USA

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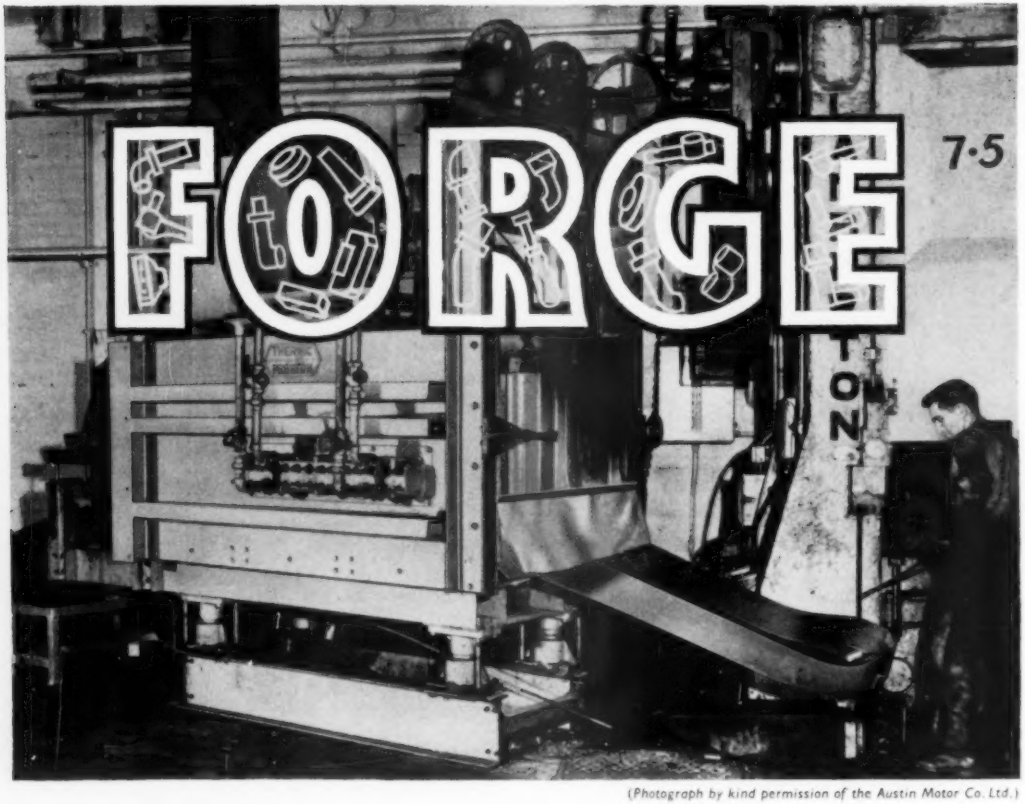

(Photograph by kind permission of the Austin Motor Co. Ltd.)

FURNACES

A wide range of standard or tailor-made mechanised forge furnaces is available, Pusher Type - Rotary Hearth Type - Conveyorised Bar End Heating, with GGC scale-free heating system or fired by gas or oil. The photograph above illustrates a small Thermic Magazine Feed Pusher furnace fired by CC Burners. Output: 7-cwts. of small billets per hour.

Thermic Equipment & Engineering Co. Ltd.
(Subsidiary Company of Gibbons Bros. Limited, Dudley)
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(Over 70% Al_2O_3)

IRON COMPOUNDS & SILICA LESS THAN 1%

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Registered Trade Mark

Bonded with appropriate aggregate this cement provides Super-duty Castable Refractory Concrete for service temperatures up to 1,800°C (3,300°F) Refractory Concrete free from Iron Compounds & Silica is now possible for the first time.

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is a product of
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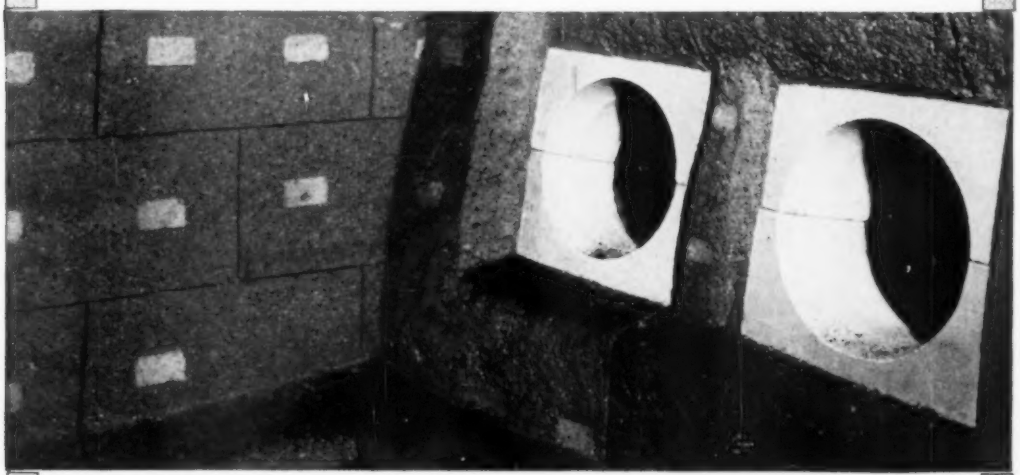

Front and side walls of a Queen Mary boiler in Tri-Mor High Temperature Mouldable, with MR 60 anchors. Burner quarls in Tri-Mor High Temperature Castable.

TRI-MOR GRADES

TRI-MOR *Standard Castable*
A medium texture refractory having negligible shrinkage up to 1,350°C. Suitable for casting special shapes or for monolithic structures. Limiting service temperature 1,350°C.

TRI-MOR *High Strength Castable*
A similar refractory to Tri-Mor Standard Castable, but specially developed to have very high mechanical strength over the lower temperature range. Maximum service temperature 1,250°C.

TRI-MOR *High Temperature Castable*
Suitable for face temperatures up to 1,600°C; has an extremely high resistance to thermal shock; used for cast in situ monolithic structures and for pre-cast refractory shapes; can be applied with a cement gun.

TRI-MOR *High Temperature Mouldable*
A plastic refractory for use up to 1,650°C: low shrinkage and a high resistance to spalling. Supplied mixed to the correct consistency for installation.

TRI-MOR *Dense "Guncrete"*
A hydraulic setting refractory with a maximum service temperature of 1,300°C. It has a high resistance to abrasion. Designed for application by cement gun, but can be trowelled.

TRI-MOR *Insulating Castable*
An insulating castable for maximum service temperatures of 1,200°C; low thermal conductivity is its main feature.

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Similar to Tri-Mor Insulating Castable but for application by cement gun.

Full details of each grade are available on request.

MORGAN Refractories Ltd

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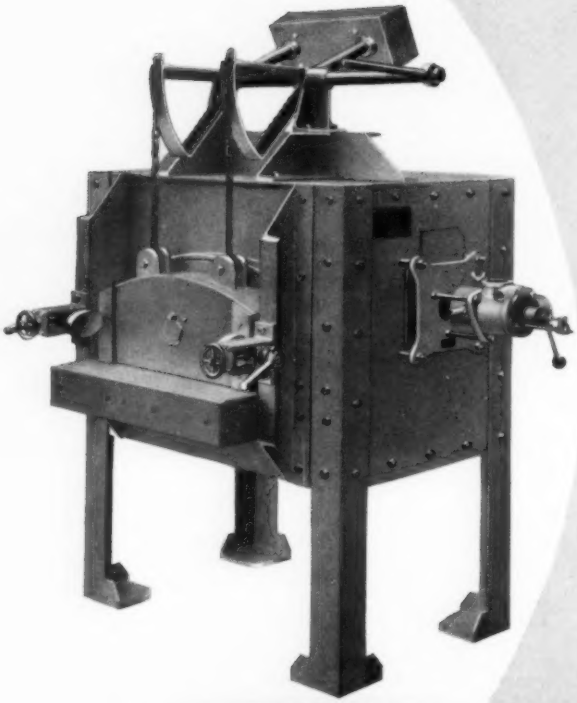
MANCHESTER FURNACES



Illustrated is a highly successful batch-type Forge or General-purpose Smithy Furnace. Fitted with Self-proportioning Burner Equipment having *single* lever control of *both* air and fuel supplies, for either Gas or Oil Firing.

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Built to dimensions best suited to meet purchaser's individual requirements with single door as illustrated, with multi-doors, or double-ended.

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Highest grade lining and hearth construction with correctly applied burner equipment ensures lowest possible operating and maintenance costs.

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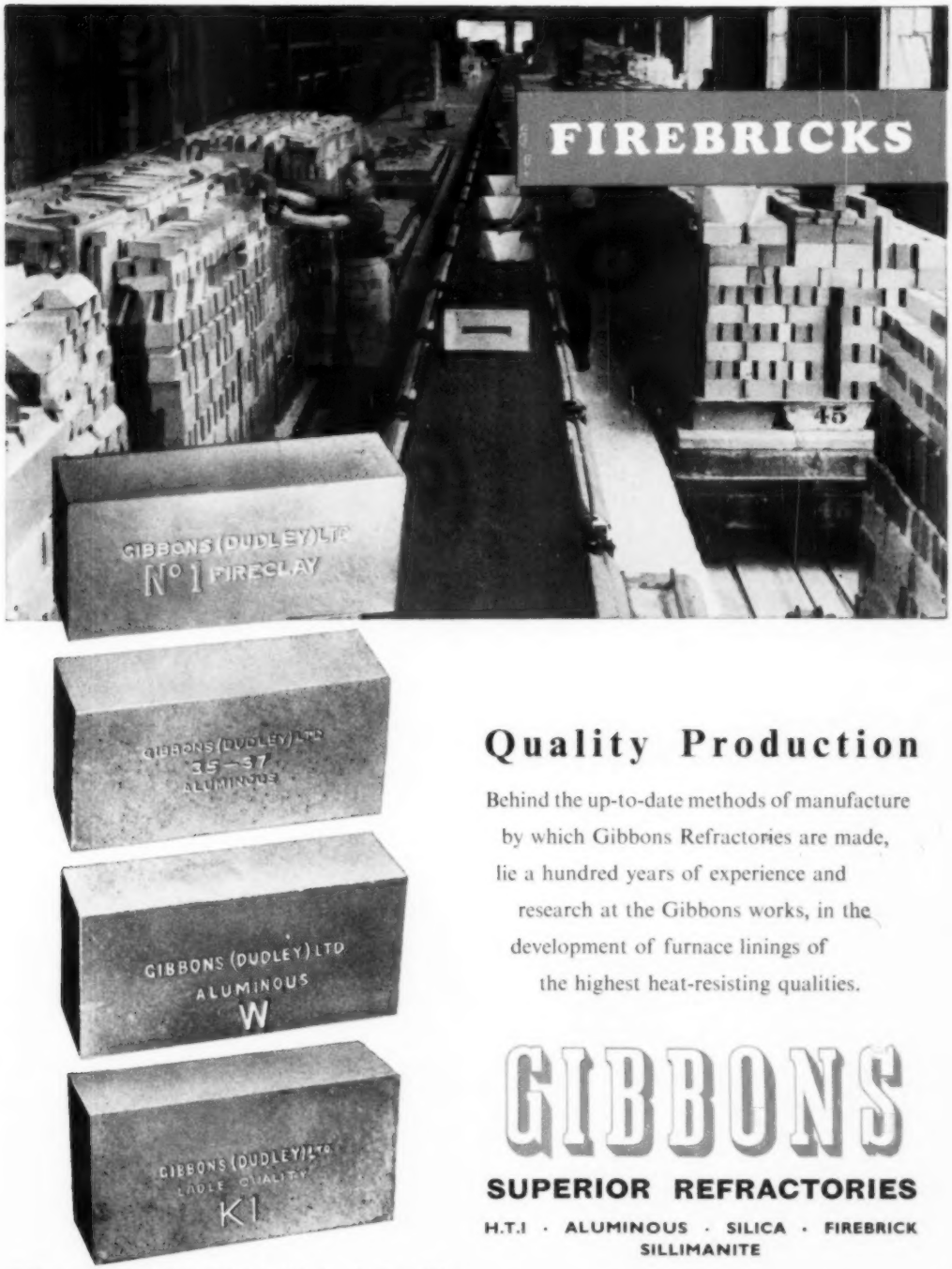

Quality Production

Behind the up-to-date methods of manufacture by which Gibbons Refractories are made, lie a hundred years of experience and research at the Gibbons works, in the development of furnace linings of the highest heat-resisting qualities.

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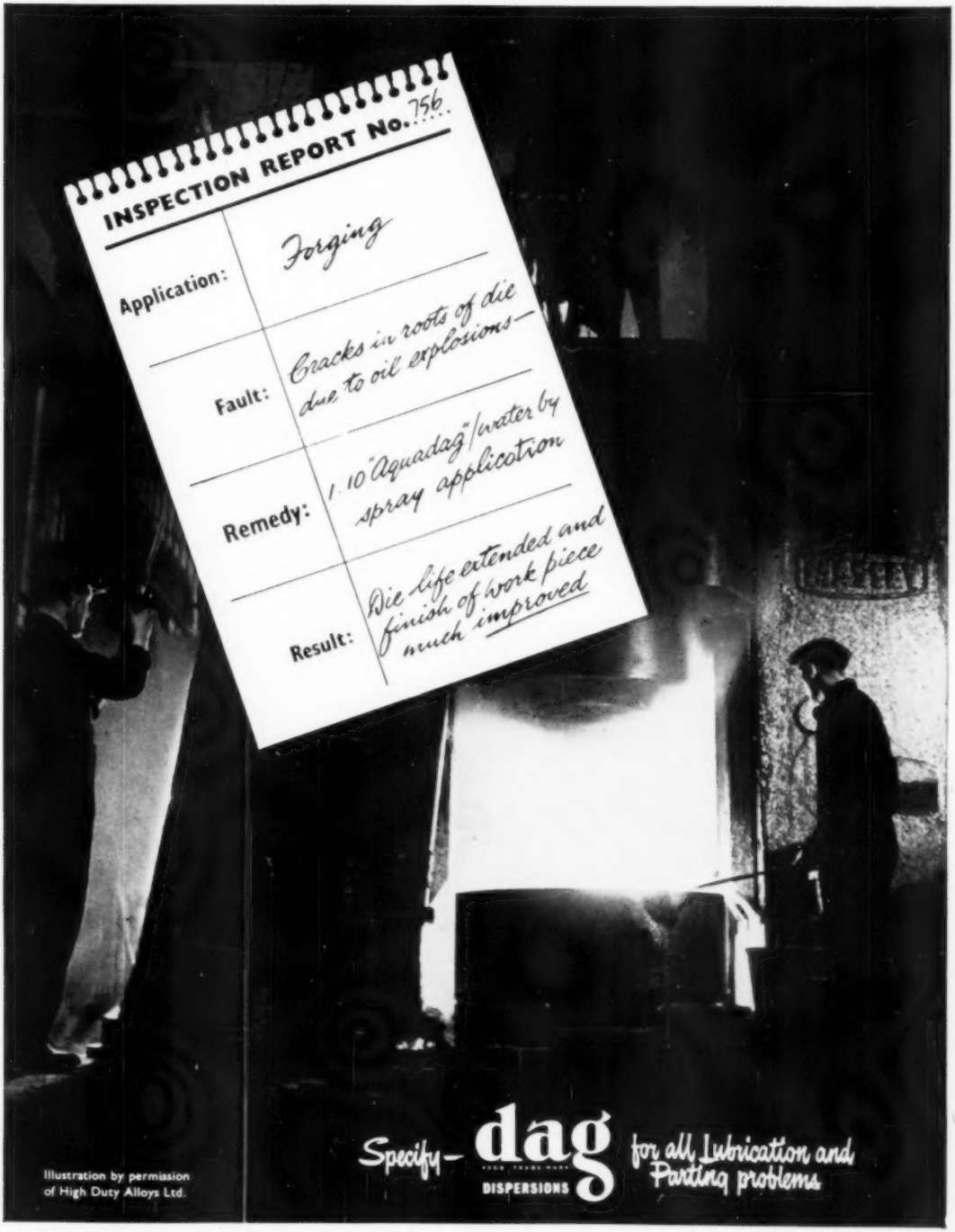
Gibbons (Dudley) Ltd., Dibdale Works, Dudley, Worcs.


INSPECTION REPORT No. 756
Application: Forging
Fault: Cracks in roots of die due to oil explosions
Remedy: 1/10 "Aquadag"/water by spray application
Result: Die life extended and finish of work piece much improved
Illustration by permission of High Duty Alloys Ltd.
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10" dia., 10" deep. Rating—4kW.

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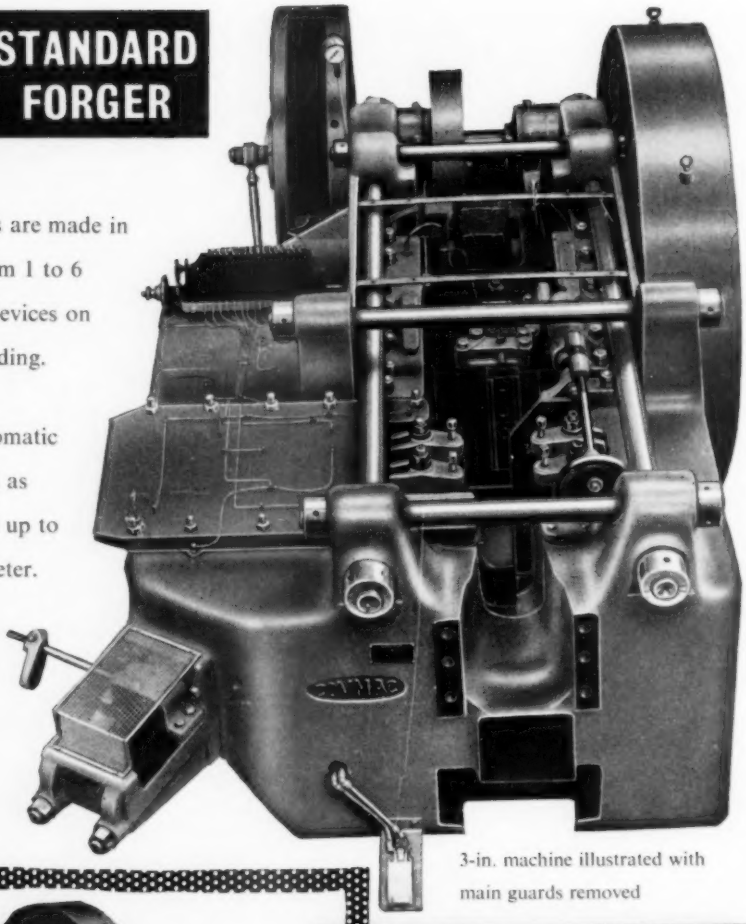
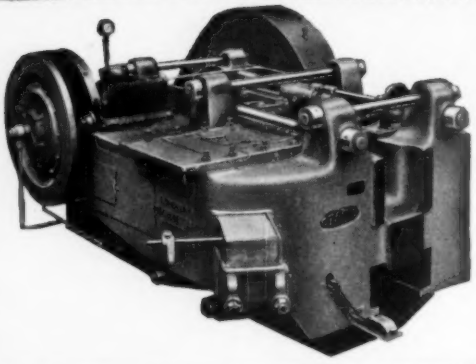
Covmac Forging Machines are made in eight sizes to take bars from 1 to 6 ins. in diameter. Safety devices on all models prevent overloading.

Covmac also make Automatic Forging Machines, as well as machines for making balls up to and including 4 ins. diameter. In addition there are three sizes of Hot Milling and Sawing Machines.



3-in. machine illustrated with main guards removed



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TYPE 992: Proportioning (stepless) Controller
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Since 1956, *when Ether Ltd. invented the transistorised indicating temperature-controller, thousands of these remarkable, direct-deflection instruments have been supplied to the STEEL, PLASTICS, RUBBER, CHEMICAL and PETROLEUM industries at home and overseas.*

Ether Transitrol Controllers, essentially simple in design, are accurate, reliable and surprisingly inexpensive. They employ no thermionic valves and they require no warming-up time. Ether Transitrol Controllers were the first in the field; they are still the finest.

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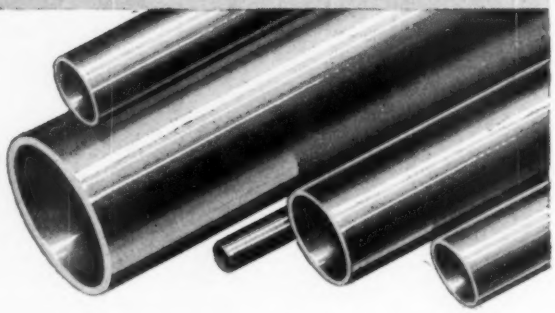
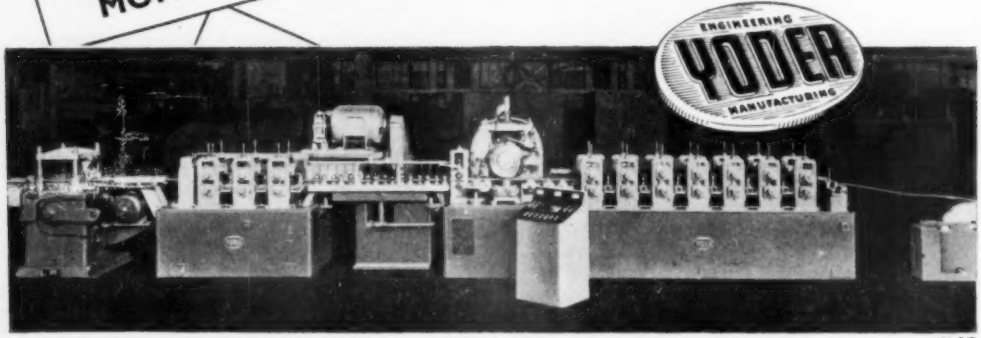


Within the last few years rapid strides have been made by Yoder in widening the scope and raising the speed of cold process electric-weld pipe and tube making. In tube mills perfected by Yoder many non-ferrous metals can be induction-welded in gauges up to ·154" and at speeds approaching those attained in resistance welding steel tubes. Further, speeds up to 250 f.p.m. are reached in induction-welding steel tubing in the same gauges. New, compact Yoder "4-in-1" Welding Transformer is the last word in resistance-welding steel pipe and tubing in sizes up to 24" diameter. More specific information, literature and estimates on request, without obligation on your part.

WICKMAN LIMITED

FACTORED MACHINE TOOL DIVISION, FLETCHAMSTEAD HIGHWAY, COVENTRY
Telephone: Coventry 74321



436 F49

Photograph by courtesy of
Geo. Tucker Eyelet Co. Ltd., Birmingham.

one, two, buckle my shoe . . .

Of course, the buckles have changed to eyelets, but the rhyme holds good, for there are two INCANDESCENT roller hearth furnaces in this factory, bright annealing 8 cwt. of steel and brass eyelets an hour.

INCANDESCENT roller hearth furnaces use centrifugally cast nickel-chromium alloy rollers for temperatures up to 1,000° C., and sillimanite compression rollers for use at higher temperatures. Both are exclusive INCANDESCENT features.

Heating is by gas-fired radiant tubes above and below the rollers giving a high rate of heat transfer and uniformity of heating. The protective atmosphere is supplied by INCANDESCENT exothermic gas generators.

INCANDESCENT

THE INCANDESCENT HEAT CO. LTD., SMETHWICK, ENGLAND

9/2/58

Brayshaw

GAS FIRED SHAKER HEARTH FURNACE

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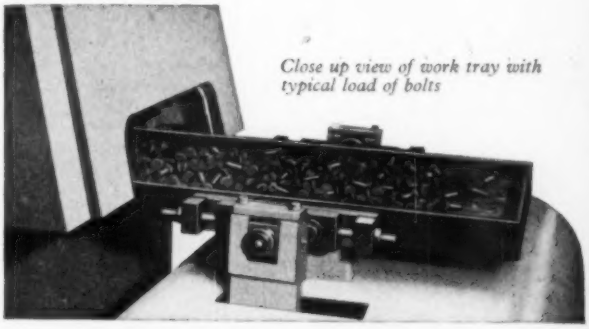

Close up view of work tray with typical load of bolts

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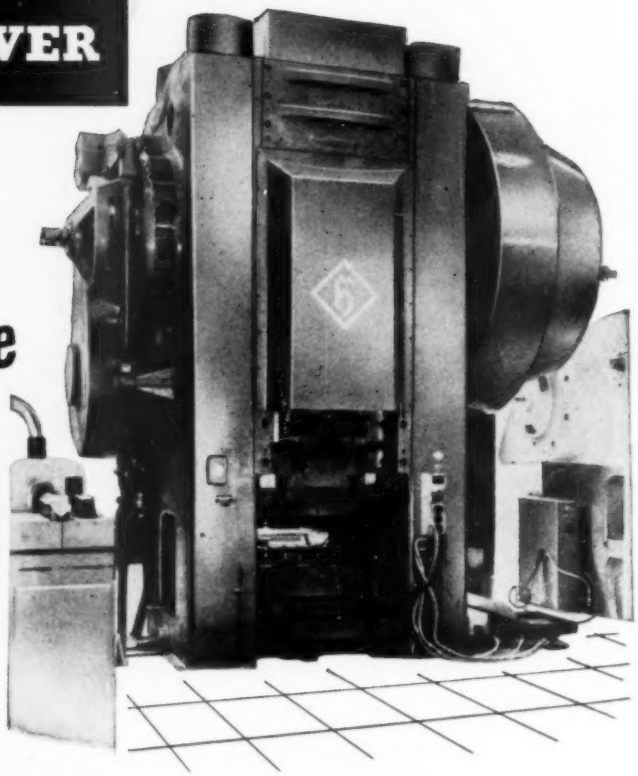

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The 'new' sciences

WE publish this month the first part of an article on operational research, an article of a kind we have been seeking for some months. The activities of those who practise operational research can, we are convinced, be of inestimable value in many fields as long as they do not fall into two extremes of error. The first of these is producing results so complicated that they can only be judged by fellow operational researchers, the other is finally coming to the surface with conclusions so obvious that the average laymen could have reached them without recourse to mathematical analysis. We hope that in the contributions which appear in this and the next two issues of METAL TREATMENT it will be demonstrated that properly conducted operational research can and does steer a course between these two potential dangers.

Operational research may fairly be termed a 'new' science. While the branch of mathematics known as statistics has been in existence for a long time, the extended application of such mathematics into problems of doing efficiently practically everything from selling soap to winning wars has only received widespread acceptance over the last twenty years or so. The general nature of these techniques, particularly as applied to problems in the metallurgical industry, will, we hope, be made clear to readers of this journal.

A science which is of the same general lineage as operational research, but is an even younger member of the class, is that known as 'cybernetics.' This, roughly speaking, is the general study of control and communication, and during the first week of this month the Second International Congress on Cybernetics has been held at Namur in Belgium. One contribution to this meeting which has come to our notice is a particularly forthright exposition of certain features of cybernetics by Mr Stafford Beer, who is head of the Operational Research and Cybernetics Department of United Steel Companies Ltd. Mr Beer challengingly entitles his address ' The irrelevance of automation.'

A good deal has been spoken and written in recent years about the impact of automation leading to a ' second industrial revolution.' The fully automatic factory is, we now know, within the realms of possibility and something very much like it may be already in existence in Soviet Russia. Because it is a possibility, the feeling has grown that it *must* come, that it is reactionary and stupid to think otherwise. In other words, as Mr Beer points out, the old ethical dictum that obligation implies possibility has been stood on its head—possibility is now assumed to imply obligation.

(Exactly the same philosophical inversion is, of course, to be found regarding space travel and sending rockets to the moon. Because it is technically feasible no effort must be spared to make it a reality, whatever the cost. Vast sums are involved, but it seems that only one or two astronomers have had the temerity to suggest that the money might be better spent in some other field of human endeavour!)

But, says Mr Beer, have we really considered what such an automatic factory implies? If

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Cold heading and upsetting

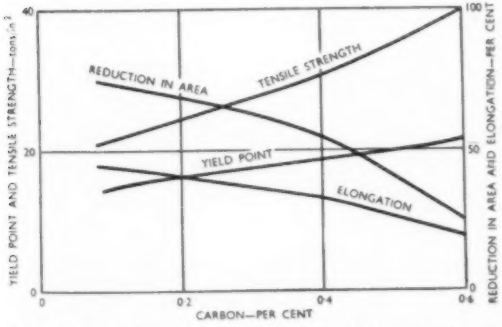
G. H. TOWNEND, M Eng, A M I Mech E, and F. B. WILSON, M B E, M I Mech E

Methods and machines used for the production of cold-headed parts are discussed as well as the materials suitable for the process. This paper was presented at the 'Conference on technology of engineering manufacture' arranged by the Institution of Mechanical Engineers, in London, March 1958. Mr Townend is manager, Mechanical Engineering Division, G K N Group Research Laboratory, and Mr Wilson is technical adviser, Guest Keen and Nettlefolds, Bolt and Nut Division

THE TERMS 'COLD HEADING' AND 'UPSETTING' refer to a process by which a head substantially larger than the shank or main body is formed on a work-piece. Many cold-headed products are axially symmetrical, and for most applications the starting material is round wire. The process is most widely used in the manufacture of fasteners because of the high production speeds attainable with economy of material. Small bolts, for example, can be manufactured at the rate of 200/min. Thread rolling is a process which is frequently combined with heading in the production of fasteners. Machinery is now available that allows both operations to be performed on one machine. Cold heading is not limited to the production of fasteners. A wide variety of shapes can be produced and special parts are being made for many industries in increasing quantities.

Materials

The most commonly used material is carbon steel. Many of the common fastener requirements are satisfied by the use of low-carbon steel. It has the merit of being low in cost, and it is easily and cheaply worked.



1 *Influence of carbon content on physical properties of cold-heading steels as hot rolled*

Fig 1 shows the influence of carbon content on the properties of the type of carbon steel used for cold heading. It can be seen that the lower the carbon content the greater the ductility and the lower the load required to deform the material. Increased carbon content will allow a stronger final product. The choice of material for heading will therefore be governed by the conflicting interests of ease of forming and required properties. Typical analyses for low carbon steels used for heading would be:

Carbon	0·15—0·20%	0·10—0·15%
Manganese	0·6 —0·80%	0·40—0·55%
Sulphur	0·05%	0·05% max
Phosphorus	0·04% max	0·05% max
Silicon		0·015% max

The basic principle in utilizing low-carbon steel is one of increasing the strength of the material by cold working and hence obtaining a fair strength from a very cheap material: but there are limits to the total amount of cold working practicable. Cold-heading wire is produced by cold-drawing hot-rolled rod. The effect of cold drawing on tensile strength, reduction in area and elongation of a 0·3% carbon steel is shown in fig 2. As reduction is increased the strength of the material is increased, but the ductility is reduced. The limitation to prehardening by cold drawing is that the material must retain sufficient ductility to allow the subsequent upset to be performed. For many heading operations it is necessary to limit the wire-drawing reduction to one draft.

Severely upset materials require a stress-relieve

it is to be economic in terms of its investment it demands an automatic market. It has little or no flexibility, it cannot afford to slow down, it demands an automatic influx of capital to stock it, to maintain it and to keep it running. Further, it demands the almost complete subservience of its manpower. The managers must initially take a vast set of almost irrevocable decisions which are then built into the plant, and having taken them they must abdicate. The labour force must accept a steady downgrading as they are shifted from jobs which disappear into jobs too trivial to be handed over to a machine.

Many people, even though they have not thought it out anything like so fully, realize that this just will not do. This vision of the industrial society of the future is nearer to hell than to heaven, and an instinctive revolt against it is inevitable, however hazy the background of ideas may be. And so, suggests Mr Beer, many of the things which really should be done are not done, processes which really should be made automatic, routines which should be entrusted to computers, and decisions which could be better taken by a machine—all these remain to be carried out in the traditional manner. A barrier of resistance is set up to hinder the work of the cybernetician, a barrier due primarily to reading the wrong aims into the new industrial revolution; to putting it forward for the wrong reasons and, naturally, receiving the wrong response. Automation, claims Mr Beer, is irrelevant to the issues before the industrial world today.

What, then, is the role which cybernetics is to play in solving the problems of an industrial society? Here, unfortunately, Mr Beer becomes rather harder to follow, probably owing to the difficulties of language. All forms of science have their own particular terminology and unless the reader is familiar with such a terminology it is virtually impossible, in the space of a relatively short address, to explain clearly what the science is all about. Cybernetics may be regarded as a thinking-tool for solving control problems, and Mr Beer points out very effectively that the systems of control which keep the human body functioning and surviving are analogous to the systems of control which operate in a large organization (*e.g.* United Steel Companies?) consisting of a central administrative headquarters and a number of subsidiary companies which are factories. Just as a man's heart, lungs, digestive organs, etc, go on functioning without a conscious directive from the brain, so we do not expect every managerial decision in one of the subsidiary factories to be made as a result of a directive from head office. Any company which tried to run on these lines would soon grind to a stop, just as a man who had consciously to control every breath and heartbeat would soon be a nervous wreck.

So far so good. Mr Beer illustrates very well the kind of analytical thinking which the cybernetician undertakes when examining systems of control and communication, and points out that automation is essentially only a special cybernetic model with close coupling, error-controlled feed-back and quick response rate. It is wholly wrong to imagine that universal automation is the goal which cyberneticians invariably seek.

What cybernetics may eventually do for the world seems at the moment to be a little uncertain, unless its practitioners are content simply to go on observing, recording and giving names to different systems of control. Is it too much to hope that they may eventually succeed in showing us how to tackle the ups and downs of the National economy?

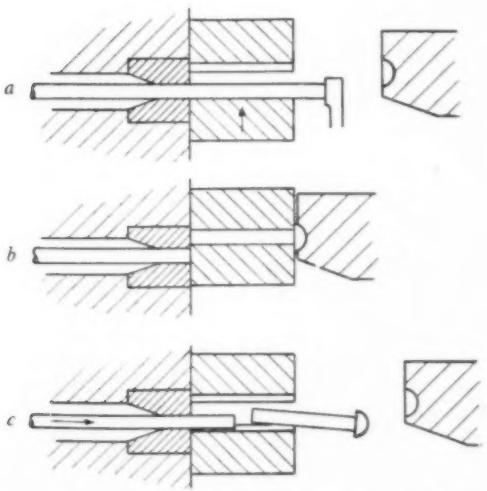
ing. Some operations, particularly extrusion, call for a heavy lubricant coat to achieve a satisfactory die life while others, such as split die work, need a light coat to avoid fouling the dies with excess soap.

For the higher-strength materials it is frequently necessary to introduce heat treatments into the preparation of the wire to achieve a starting material with sufficient ductility and in a soft condition. For very severe heading operations even low-carbon wire may be heat treated. The heat treatment is introduced between a preliminary drawing and a final very light drafting in the wire mill. This gives a much softer stock, with a bright drawn and lubricated finish, than could be obtained by direct drawing.

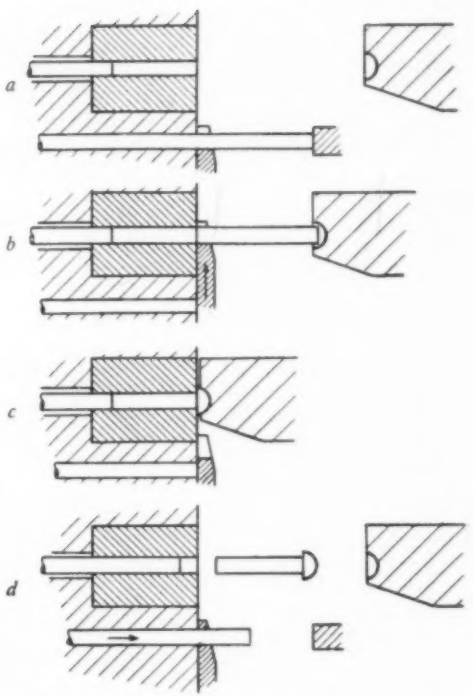
The heat treatment consists of annealing either above the critical range (900—950°C) or below the critical (650—700°C) producing pearlitic and spheroidized structures respectively.

Spheroidizing treatment takes longer but produces a wire with better heading properties. Being more expensive, spheroidizing is only used for very difficult upsets. Most bolt-forming operations, using wire in the lower ranges of carbon content, can be accomplished using annealed wire.

A recent development to enable steel to be used in its most ductile condition is to replace the final light drawing operation by a zinc phosphate treatment followed by a lubricant dip. The work hardening due to drawing is thereby avoided and a well-lubricated surface for cold working is obtained.



4 *Diagrammatic representation of the operation of a single-blow split-die header*

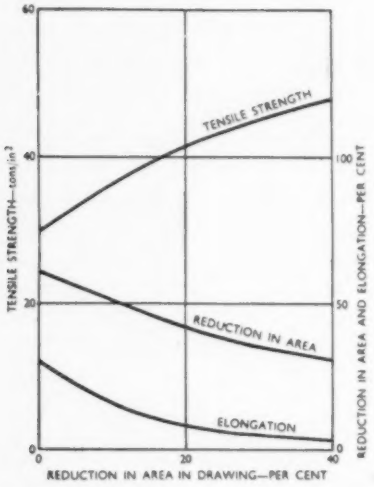


5 *Diagrammatic representation of the operation of a single-blow solid-die header*

Processes

Cold-heading processes are carried out on mechanical presses and the simplest form of machine is the single-blow header. Fig 4 is a diagrammatic representation of the operation of a split-die single-blow header. Wire from the coil is fed until limited by a stop *a*. The split die then closes, cutting off the wire. The punch advances and forms the head *b*. The punch withdraws, the split die opens and wire feed commences, ejecting the finished blank *c*.

An alternative form of single-blow header using a solid die is shown in fig 5. Wire is fed until limited by a stop *a*. A cut-off knife shears a length of wire and transfers it to the die mouth *b*. The wire is pushed into the die by the advancing punch which then forms a head *c*. An ejector pin pushes the completed blank out of the die *d*. The solid die header produces a more accurate blank than the split die header. Another advantage is that it is possible to extrude part of the shank when it is pushed into the heading die. This operation is not possible on a split die header. By extrusion is meant the reduction of part of the shank by a



2 *Effect of cold drawing on tensile properties of 0·3% carbon steel*

or process anneal at about 500—550°C to restore some degree of ductility to heavily worked parts. This involves some loss of strength, depending partly on the temperature of the anneal. While the necessity for a process anneal depends on the severity of the forming operation, a given shaped part may or may not require a process anneal, depending on the method used for the forming. More will be said about this later. However, it is worth noting here that it is possible to manufacture from low-carbon steel bolts with certain head forms with a tensile strength of 45 tons/sq in. which may be safely used without process annealing.

Where a cold heading operation is severe, a rimmed steel is frequently used. The outer skin of this type of steel is very ductile because of its low carbon content, so reducing the risk of surface cracks being formed in the product. The use of this type of material is limited to carbon contents not exceeding about 0·12% carbon.

The presence of sulphur and phosphorus as impurities in the steel has an adverse effect on the ability of the steel to be cold worked. Sulphur precipitates as sulphides and hence reduces the available ductility of the steel, but the effect is unimportant below 0·05%. On the other hand, a high sulphur content improves the machinability of the steel. For example, it makes the tapping of cold-formed nuts easier. In certain cases the high nitrogen content of acid steels is useful in improving machinability of headed products.

Since the heading operation increases the diameter of some parts of the work-piece, considerable circumferential strain is imposed. Wire of good surface quality must therefore be used if defects are to be avoided. The presence of seams and laps in the surface of the wire must be avoided, and special precautions such as ingot dressing or heavy scaling during or after the rod-rolling stage are sometimes taken to provide wire of faultless surface quality. The presence of any central unsoundness or pipe may also cause difficulty, particularly during thread rolling.

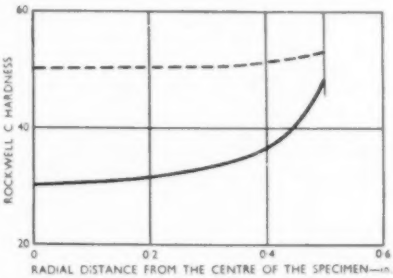
For manufacture of products which require a higher strength than can be obtained from cold-worked low-carbon steel, a medium-carbon or alloy steel is used, the required properties being obtained by heat treatment. The use of medium-carbon steels is limited to sections which can be through-hardened by oil quenching. The use of a more severe quench may result in cracking. To produce the maximum physical properties it is necessary to harden the whole of the cross-section. Fig 3 compares the hardness penetration of 1-in.-dia specimens of 0·48% carbon steel and a nickel-chromium steel (1·25 Ni 0·65 Cr) when oil quenched.

The use of cold heading is not limited to ferrous material. Copper, silver and certain brasses and bronzes are all readily headed.

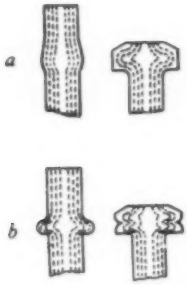
For heavy brass upsets, the copper content of the brass should be at least 62% and impurities should be controlled, particularly lead and iron. Limited upsets can be performed on leaded brasses.

Preparation of material

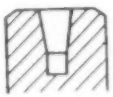
In most cases cold-heading wire is manufactured by dry drawing from hot-rolled rod, using a metallic soap as a lubricant. The rod is first pickled to remove the rolling scale and then given a coating of lime. This coating makes the soap lubricant more effective both in the drawing operation and in the subsequent heading operations. The thickness of lubricant coating applied to the wire can be partly controlled by the heaviness of the lime coat-



3 *Comparison of the hardness penetration of two steels when oil-quenched*
——— 0·48% carbon steel
— — — — 1·25% nickel, 0·65% chromium steel



9 *Influence of first-blow form on the grain flow*



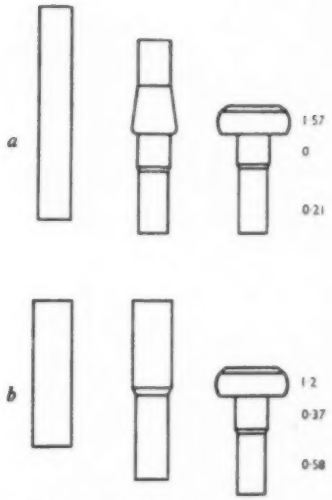
10 *First-blow heading punch*

upset, when more than three blows are required. An annealing operation can be carried out before the work is reheaded. Fig 8 shows the stages in forming two large upsets using single- and two-blow reheading.

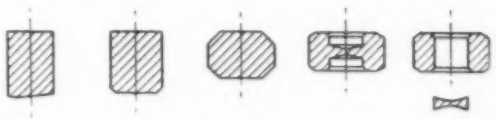
While the dimensions of the finished product are controlled by the shape of the final-blow punch, the design of the intermediate-blow punch form will have an influence on obtaining satisfactory grain flow in the finished product. For example, a first-blow form shown in fig 9*a* would produce a good head while that shown as fig 9*b* would produce a bad grain flow and probably laps in the head.

The type of first-blow punch most generally recommended takes the form of a cylindrical section with a cone below (fig 10). The following considerations usually apply to the design of first-blow punches; but certain types of work, such as products with short shanks, may need some modification in the design:

(1) The cylindrical portion of the punch is slightly larger than the wire size and supports a portion of the wire. As mentioned above, the unsupported length is limited by buckling, and should not exceed 2·6 times the wire diameter. This value is somewhat larger than the unsupported length allowable with a single-blow punch because some support is obtained from the cylindrical part of the punch. The length of the part of the blank deformed after the first blow will be determined by the cone angle of the punch. The larger the cone angle the smaller will be the upset length, so that the total length of blank to be upset in the second blow will be smaller.



11 *Stages in forming a bolt blank*
a By two-blow heading
b By progressive heading

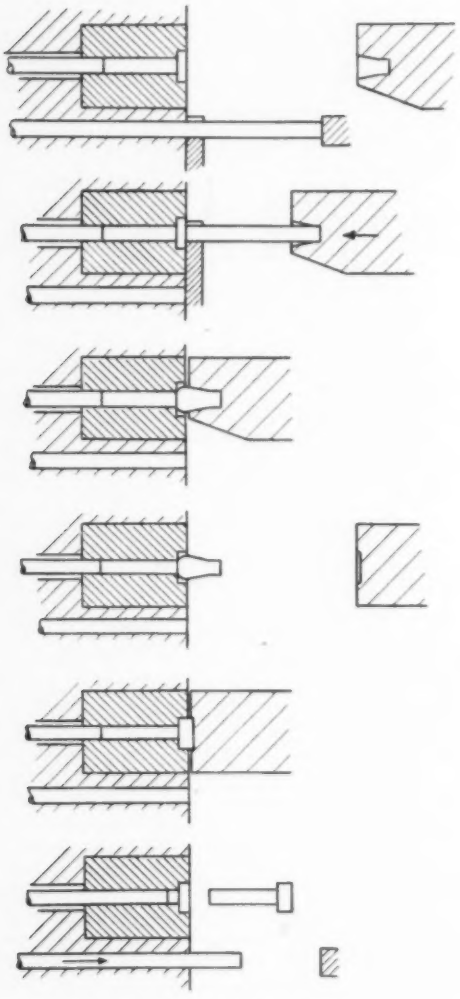


12 *Stages in cold forming a nut blank*

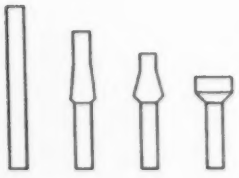
(2) The first-blow form must not buckle at the second blow. A small cone angle (that is, a long cone length) and long length of cylindrical portion both tend to make the second blow unstable, and for a given cone angle there is a limit to the allowable length of the cylindrical portion. However, the larger the cone angle the more pronounced the transition from the conical to the cylindrical section and the greater the tendency to form folds in the grain flow of the final product. This effect is not marked up to included cone angles of 18 deg.

To obtain the best grain flow, the smallest cone angle consistent with avoiding buckling during heading should be used; large upset ratios, however, make it necessary to use large cone angles to obtain freedom from buckling during both blows. Above an upset ratio of about 4 an ideal grain flow is not usually achieved. The table on page 358 shows the relation between upset ratio and necessary cone angle.

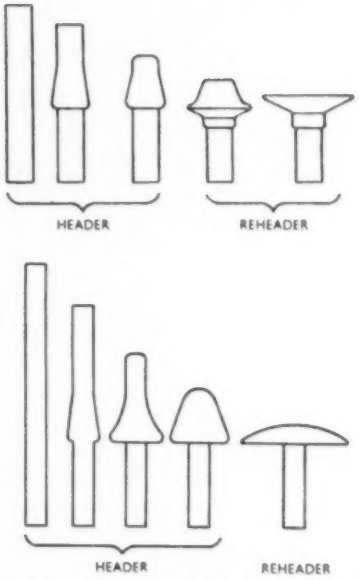
So far, machines in which the work-piece is formed by one or more blows while in a single die



6. *Operation of a two-blow solid-die header*



7 *Stages in forming a head in three blows*



8 *Formation of large upsets by single- and two-blow reheading*

conical-shaped die which is integral with the heading die.

In heading, the ratio of the length of wire upset to the original diameter of the wire is termed the 'upset ratio.' As the upset ratio is increased there is an increasing tendency for the wire to buckle and so to produce unsatisfactory heads. The permissible upset ratio will be influenced by squareness of cut-off and by the lubrication, surface condition and shape of the punch. The maximum possible length upset in a single blow is unlikely to exceed 2·3 times the diameter.

If heads containing a greater volume of material are required, more than one blow is used. The principle is to support part of the wire in the punch during the first blow, thereby avoiding buckling. A second punch then shapes the material to the final form while it is still held in the same die. The operation of a two-blow header is shown diagrammatically in fig 6. By the use of two blows the permissible upset ratio can be increased to about $4\frac{1}{2}$. Similarly, by the use of three blows the upset ratio can be still further increased. Fig 7 illustrates the upset of a large head in three blows. While it would be possible to increase further the number of blows, and the upset ratio, in practice the decreasing ductility of the material would generally preclude this without intermediate annealing. Single and two-blow heading are by far the most common.

Machinery exists for reheading a partially formed

a two-blow header. Fig 11*a* shows the stages in forming a bolt on a heading machine. The starting material is of shank size and the thread-rolling diameter is extruded from this size, while the head is upset in two blows to a cheese shape, prior to trimming to hexagon. The degree of upset or reduction by extrusion may be expressed as $\log_e A_1/A_0$ where A_1 is the final cross-sectional area of the part of the bolt considered and A_0 is the cross-sectional area of the original wire. Values of degree of upset for a bolt formed in the above manner are shown in fig 11*a*.

When a progressive header is used, the starting material can be larger than the shank size. The first operation reduces a portion of the blank to shank size (fig 11*b*). The second operation reduces a part of the extruded blank to thread-rolling diameter and upsets the cheese for the head. By this process the shank receives some cold work while the head receives less compared with the two-blow process previously described. The degree of upset, and so the degree of work-hardening in the various parts, is made more uniform as shown in fig 11.

By starting with wire above shank size the upset in the head is reduced, so that it is often possible to produce satisfactory bolts without the need for subsequent heat treatment. The method of manufacture described above is, of course, only one of many possible tool arrangements on a progressive header. This flexibility is most useful in adapting the machine to a wide variety of requirements.

While the degree of upset has been defined above a $\log_e A_1/A_0$, this figure is only a measure of the average amount of deformation. The actual deformation which occurs in a head is by no means uniform and the degree of work hardening will vary throughout the head.[1]

An important class of machinery not so far mentioned is used to form nuts cold. By one such process round wire is upset to hexagonal form and the central hole is partly formed from both sides of the nut. The material remaining in the hole is pressed out. These operations are carried out on a transfer type of machine and are illustrated in fig 12.

To summarize, the amount of material upset is limited by the stability of the material during the forging operation. The degree to which the material can be upset is more a function of the ductility and surface quality of the material. The size of work which can be upset is determined by economics. The practical limit appears to be about 1-in.-dia wire with a length of 6 to 9 in., although machines with a capacity up to $1\frac{1}{4}$ in. dia exist.

The processes described above are capable of forming a wide variety of shapes. As with other processes it is, however, necessary to let the advantages and limitation of the method of manufacture influence the design of component. The following principles in design are usually applicable to cold heading, although exception can be found to them:

Design considerations

(1) Limit the amount of material upset to the minimum volume which will meet the requirements of the component. This is subject to the exception that large thin heads are difficult to form.

(2) Keep the diameter of the head to a minimum to meet requirements.

(3) Avoid square inside corners or sharp junctions between head and shank if possible.

(4) Steel becomes more difficult to head as the carbon content increases. Complex shapes should be specified in low-carbon steel whenever possible.

(5) Axially symmetrical components are easier to form than off-centre or eccentric parts.

(6) When a shank requires a stepped diameter allow for a taper at the step.

(7) Very long extrusions should be avoided.

Applications

The range of products which can be made by cold heading is so wide that it is only possible to illustrate a few applications. Though cold heading finds its greatest application in the production of standard fasteners, its use in this field is well known. Figs 13 and 14 illustrate a number of special products.

Reference

(1) J. Billigmann, 'Stauchen und Pressen,' p 120. Carl Hanser, Verlag, Munchen, 1953.

Birlec in South Africa

Consolidating their venture into the South African market made early in 1956, Birlec Ltd announces that a Johannesburg branch office, under the management of Mr S. G. King, has now been formed. Situated between Boksburg and Benoni, the new branch will deal with all enquiries including project design and engineering service work. The postal address is P O Box 99, Witfield, Transvaal.

It is expected that the chief demand will be for melting furnaces, particularly for those used mainly in making alloy steels. Whilst certain special equipment and parts will continue to be imported from the main Birmingham works the majority of the equipment will be manufactured locally by the Firlst Electro Corporation.

In the Federation of Rhodesia and Nyasaland the British Thomson-Houston Co (Central Africa) (Pvt) Ltd will continue to act as Birlec agents, but the services of the new branch will now be fully available to Birlec furnace users in the Federation.

have been considered. An important class of machines are those in which the work is formed

Upset ratio	Included cone angle, deg
3·8	12
4·0	15
4·3	20
4·5	25

in a series of dies and punches, the work being automatically transferred between stations. At each stroke of the machine the various stations on the machine carry out their operation and so one complete component is produced per stroke of the machine. It is possible to perform extrusions at each die in addition to a heading operation; other operations such as shearing or trimming a round head to hexagonal form can also be included. One such machine is the National Boltmaker. This machine includes stations for pointing and thread rolling. While these machines were developed principally for boltmaking a great variety of products can be formed on them.

Some of the advantages of the progressive or transfer header can be seen by comparing the manufacture of a bolt on such a machine with that on

13 *Small parts produced by cold heading and upsetting*

14 *Typical small items produced by cold heading and upsetting*

The 'Mercast' process

Use of frozen mercury pattern

LEFT *Investing the frozen mercury pattern*

Sankey-Telcon Ltd, a company owned jointly by Guest Keen & Nettlefolds Ltd and the Telegraph Construction & Maintenance Co Ltd, is the sole operating licensee of the 'Mercast' process outside the U S. This method of precision investment casting has been operating on a production basis for about 18 months at Telcon Works, Crawley, Sussex. Frozen mercury is used as the pattern material enabling castings of better quality and greater intricacy to be produced than those from wax or plastic patterns. A brief description of the new factory at Telcon Works was given in 'Metal Treatment,' August, 1956

THE FACTORY IS DIVIDED into three main units: the pattern and mould making, the foundry and finishing, and the toolroom.

The essential plant in the pattern and mould-making shop consists of two insulated tanks, one known as the freeze tank and the other as the dip tank. These tanks are maintained at a temperature of –63 C to –67 C and –60 C to –63 C respectively by means of a mechanical refrigeration unit housed in a totally enclosed room. Mercury in the dies is frozen in the freeze tank and these frozen mercury patterns, after extraction from the dies, are invested with a zircon-base ceramic in the dip tank. To speed up the freezing the freeze tank is filled with acetone to provide an adequate thermal sink. Because of the consequent fire hazard all lighting and electrical equipment in this shop is flameproof and, wherever possible, compressed air is used for operation of hoists, slurry stirrers, etc, and flame-proof electric motors are used for slurry mixing. Ancillary equipment includes:

A melt-out rack It is here that the invested frozen mercury patterns are allowed to warm up when the mercury melts and runs out of the moulds. Directional melting may be induced by projecting a stream of liquid mercury at room temperature on to specific sites on the pattern. The mercury runs into a trough underneath the melt-out rack where it is covered by a layer of acetone which suppresses the formation of mercury vapour. The mercury is returned from this unit through a cleaning system back to the freeze tank for the making up of further patterns.

Warm-up tanks These tanks are filled with acetone and are maintained at room temperature by a steam heating coil. As the tools are dissembled after the freezing operation they are returned to this tank where their temperature is brought up to room temperature prior to reassembly and following through the next cycle.

Slurry mixing unit This unit is used intermittently for the making up of the investment slurries. It consists essentially of an insulated tank fitted with two stirrers operated by flame-proof motors. Because of the intermittent nature of its use this tank is cooled with solid CO_2.

Foundry and finishing

Apart from melting furnaces the foundry is equipped with furnaces for firing moulds and for preheating mounted moulds for the casting operation. High-alloy steel is melted in 20-lb-capacity, rocking-hearth, indirect-arc furnaces or in 20-lb-capacity high-frequency spark-gap furnaces. Aluminium alloys are melted in a 50-lb-capacity electric-resistance furnace of the bale-out type, and a 100-lb-capacity gas-fired tilting furnace is used for the melting of copper-base alloys.

The green moulds from the pattern and mould-making shop are first dried in an infra-red cabinet and are then fired at high temperatures in a trolley-

New forging techniques

Revolutionary forging methods are being developed by the U S Air Force, claims Mr R. L. Albrecht in 'Metal Forming and Fabricating,' July 1958. Mr Albrecht is deputy chief of the Basic Industry Section, Manufacturing Branch of the Air Material Command; a summary of his remarks is given below

MANY NEW FORGING TECHNIQUES have been developed within the past several years and many new and unorthodox methods are being proposed for development. Forgings, as in other phases of the art of working metal, are undergoing a rapid, revolutionary process.

Up until this time, high die cost, long lead time, die sinking, machining and general high overall costs have made the use of forgings in aircraft and missiles expensive. However, many new processes are being tried to reduce these costs, and still improve the basic product.

Explosive forging

Outstanding among these processes is explosive forging, *i e* making forgings by the application of extremely high energy to the billet material.

If such a method can be successfully developed, and soon, the entire metal-working industry might have to rearrange its thinking. Previously, when working metals, be it by forging or extrusion, deformation rates were of the order of about a few hundred feet per minute at the most. The use of explosives, however, would give deformation rates of 5 to 15,000 feet per second. Deformation rates of this magnitude have in the past been entirely beyond the realm of even very forward thinking.

Based on the results of experimental work to date, it seems that the metal may not even have to be heated in order to form it. In other words, room temperature deformation. If this is the case, then contamination, decarburization and scaling will be things of the past.

How is an explosive process of this type to be developed? We propose to place a piece of billet material over the cavity and above this to place an explosive charge. We feel that the shock wave generated by the explosion will deform the metal properly into the die cavity. The resultant forging should have physical properties above and beyond the ordinarily forged materials and with only a minimum of capital equipment.

Forging with high-frequency vibrations

Another possible new forging process is high-frequency forging. The purpose of this proposed development is to investigate a process for forging ferrous materials to closer dimensional tolerances than those presently obtainable by conventional forging methods, and to eliminate the need for costly machining.

The metal is deformed by using normal forging pressure coincident with a high order of superimposed vibration. These vibratory forces should allow for better die fill-out in addition to the saving brought about by reduced machining.

Another project is to develop coatings to prevent scale or contamination on hot-worked materials. When forging steels, because of the temperature required, scale is formed in abundance. This results in material waste and also poorer forgings. Already research has made some progress in developing a coating for titanium. This coating for titanium prevents contamination during heating.

Cold-rolled turbine discs

Also under development is the cold-roll forging of turbine engine discs. One of these experimentally produced discs shows that the finish and tolerances are extremely good. Fabrication by this technique will eliminate a very large amount of the machining that is normally required when these discs are forged from hot billets.

In the area of scale and contamination prevention, it might be possible that in the not too distant future an entire forging operation might be carried out in a sealed inert atmosphere chamber, utilizing a gas such as argon. Using extensive automation, entire forging plants may be operated in this manner. The only humans involved would be highly technical operators for close control of the process. These people would have to be clothed in some types of pressure suits. As to pressure suits being cumbersome or dangerous, it should be pointed out that Air Force pilots wear these suits and still do their job.

Faster methods for cutting billets

Of vital interest, and one that should advance the 'state of the art' is high-speed billet cutting. Forging and extrusion plants today receive billet material from the mills. These billets, in turn, must be cut into multiples for use in the various fabrication methods.

New and faster methods of billet cutting are being developed. One of these is electrolytic cutting. A second is explosive billet cutting which may allow for the instantaneous division of multiples from the original billet.

Attempting to equalize transverse and longi-

continued on page 362

hearth electric furnace. The fired moulds are mounted in various ways and preheated to the required temperature for casting in trolley-hearth electric furnaces.

The finishing section is equipped with a high-speed handsaw, abrasive cut-off machine, shot and vapour blast cabinets, grinders, linishers and the usual bench finishing tools.

Typical castings

A typical casting which is currently being produced is an outer flange segment which is welded to the exit of a combustion chamber in a jet engine. Guide vanes formed from sheet metal are welded in each of the aerofoil slots, a lip being cast on to allow successful welding to be carried out. The part is cast in Nimocast 90, a heat-resisting alloy containing titanium and aluminium.

Another type of casting produced is a multi-bladed rotor cast in an austenitic heat-resisting steel. Close control on dimensions is essential, especially in respect of concentricity, or difficulty in balancing results.

Other castings produced include stator blading for industrial and aircraft gas turbines. The standards of acceptance are very high in both cases and dimensional accuracy must be maintained consistently. Such castings are now being produced by vacuum melting and casting, this being especially useful for high-temperature alloys, containing easily oxidizable constituents, such as titanium and aluminium.

Advantages of the Mercast process

Mercury as the pattern material has the following advantages: (1) Solid liquid expansion is small and, therefore, thin shell moulds can be employed without fear of cracking the shell.

(2) It readily welds to itself under light pressure so that accurate and intricate patterns can be produced by abutting or ' booking ' simple component patterns together in a precision jig. This characteristic also enables cores to be positioned in sites inaccessible in other techniques.

(3) Its high density and good wetting characteristics permit perfect reproduction of minute detail.

The zircon-base refractory material, free from all moisture, combined or absorbed, together with the mercury pattern, enables a shell mould to be produced which, after firing, is strong, stable and inert to most alloys. Freedom from porosity, shrinkage cavities and blow holes, development of controlled grain size and consistency of dimensions, are all achieved. The particle size of the zircon-base refractory investment material is selected in relation to the metal being cast and enables fine surface finish of the casting to be attained.

The shell moulds enable chills to be used allowing directional solidification to be induced, even in those cases where rapid changes in cross-section occur. The strength of the thin shell mould is sufficient to withstand the most severe mechanical shock associated with casting by suction, vibration, inversion, centrifugal or vacuum casting methods.

New forging techniques

concluded from page 360

tudinal tensile strengths in forgings is another endeavour. By proper control of ingot production and subsequent fabrication, we believe these properties can be equalized. When this programme is completed, metals with unthought-of strengths are expected to be obtained.

Better methods for producing dies is an area in which we feel great strides will be made in the near future. Keller machining of these dies is now the standard shop practice. This is a time-consuming operation and, of course, costly. Numerically controlled machining and electrical discharge machining are two methods now under development and test to alleviate this loss in time and cost.

Cast impression forging dies also is another area in which we are interested. Any or all of the above methods could reduce the cost of the resulting forged product, and that is our aim.

Precision forging process

By precision forged is meant a forging with absolute minimum weight and maximum strength. Heretofore, the machining cost of forgings has been considerable and this will increase under today's operations as we move into higher temperature materials.

We have already produced precision aluminium and titanium forgings and are now working with high-temperature magnesium and steel. The production of precision forged gears has long been the desire of industry. We now have such a process in the development stage.

Most industrialists are familiar with heavy presses. These presses can exert forces up to 100 million lb, and coincident with these forces are work areas up to 240 sq ft. Up to this time, these presses have been used exclusively for the forging of aluminium and some steel aircraft structural components. We are now looking to other areas of use, such as continuous forging of missile skins, production of nose cones and rubber pad forming. These presses have been restricted in use up to now but we anticipate greater and more intensified usage in the future. This usage can only come about after full co-operation between the missile manufacturers and the forging press operators is established.

Liquefied petroleum gases

and their uses in metallurgy

C. F. PORT

The increasing importance of liquefied petroleum gases in the metallurgical industries, as may be seen in their use for the production of protective atmospheres for heat-treatment processes, makes it desirable for metallurgists to become familiar with their properties and potential applications. This article by Mr Port, of Bottogas Ltd (controlled by Shell-Mex and B P Ltd), summarizes the properties and specifications of commercial butane and propane and gives details of their handling and metallurgical applications

AMONG THE WORLD'S MAJOR SOURCES of energy are fuels from petroleum and, of these, liquefied petroleum gas constitutes the newest of our industrial fuels. They are products composed of the hydrocarbons propane, propene, butanes, and butenes. Those consisting essentially of the C_3 hydrocarbons propane or propene, or mixtures of both, are sold as commercial propane, while commercial butane is predominantly a mixture of the C_4 hydrocarbons butane and butene and their isomers.

The general term liquefied petroleum gases is used for both these products, often shortened to L P gases, which will be used in this article. The products are stored and transported in liquid form and put to use as a gas, to which the liquid is converted by the release of pressure when the valve is opened on a container, or by the application of warmth in a vaporizer. The liquid produces many times its own volume of gas, about 275 cu ft from 1 cu ft of liquid in the case of propane.

Liquefied petroleum gases are firmly established in the U S A as industrial fuels and to a lesser extent on the continent of Europe. In America, where they are largely derived from natural gas, sales total many millions of tons.

Liquefied petroleum gases were not marketed in this country until 1934, but by 1939 their use had become fairly widespread, butane as a domestic fuel and propane for industry, both grades being distributed in cylinders having capacities of up to 100 lb. Since then there has been a considerable increase in their use, which today amounts in total to over 60,000 tons per annum, of which some 20,000 tons are for industrial applications.

With the post-war expansion of the U K refineries, increased quantities of L P gases have become available, and this source of heat is taking its place in industry throughout Great Britain. A further impetus was given in 1954 when bulk deliveries in 4-ton lots were introduced, special vehicles with pressure vessels being designed for this purpose.

Properties of L P gases

Liquefied petroleum gases are usually a mixture of two or more hydrocarbons, as already mentioned. It follows, therefore, that the properties and composition could vary somewhat. In order to maintain a high and reasonably uniform standard of quality, specifications were drawn up by the Liquefied Petroleum Gas Industry Technical Committee, an association of U K producers and distributors of liquefied gas formed in 1947. These specifications are accepted by all U K producers of L P gases and are as follows.

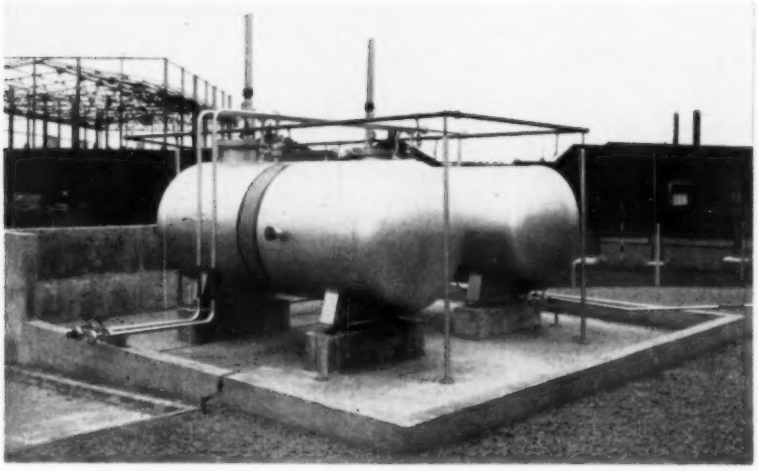
Commercial butane

Commercial butane shall be a hydrocarbon mixture consisting predominantly of butanes and/or butenes. It shall not contain harmful quantities of toxic or nauseating substances and shall be free from mechanically entrained water. It shall have the following composition and properties:

(*a*) The total content of C_5 and higher hydrocarbons shall not exceed 2 moles % calculated as normal pentane.

(*b*) The maximum vapour pressure at 45° C shall be 85 lb/sq in. gauge as determined by the N G A A method.

(*c*) The total sulphur present in the gas shall not exceed 0·02% by weight as determined by the current edition of I P Method 107.



2 *Two 5-ton propane storage vessels*

carbons shall not exceed 10 moles % calculated as normal butane.

(*d*) The maximum vapour pressure of 45° C shall be 255 lb/sq in. gauge as determined by the N G A A method.

(*e*) The total sulphur present in the gas shall not exceed 0·02% by weight as determined by the current edition of I P Method 107.

(*f*) The gas shall not contain more than 2·0 grains of mercaptan sulphur per 100 cu ft at S T P (sat) as determined by the current edition of I P Method 104.

(*g*) The hydrogen sulphide content shall be nil as indicated by moist lead acetate paper exposed to the gas.

(*h*) The odour of the gas shall be distinctive, unpleasant, and non-persistent and shall indicate the presence of gas down to concentrations in air of one-fifth the lower limit of inflammability.

Close control is maintained at the producing centres to ensure that all L P gases sold in the U K comply with the specifications.

Table I shows average properties of L P gases including those not covered by the specifications shown above.

Production of L P gases

Butane and propane are separated from crude petroleum at the refinery during the primary distillation process, in which the lighter petroleum products are obtained. A small proportion of gases consisting largely of butane and propane is not recovered in this process, and these are led off from the condensing system from which the petrol, kerosene, etc, are obtained, redistilled under pressure, and the liquefied petroleum gases separated. After any necessary refining treatment, usually an alkali wash to remove sulphur compounds, the liquefied fuel gases are pumped to pressure containers where they are stored as liquids.

In addition to the L P gases naturally present in the crude petroleum, appreciable quantities are formed when certain heavy petroleum fractions obtained from the distillation process are ' cracked ' to produce more petroleum spirit.

Liquefied petroleum gases separated from the crude by straight distillation processes contain only the saturated hydrocarbons (butane and propane), but those obtained by a ' cracking ' process contain the unsaturated hydrocarbons butene and propene as well.

Vaporization of L P gases

Butane and propane have been referred to as together constituting liquefied petroleum gases. They are similar in many ways as might be expected from their close relationship, but differ essentially in their boiling points and consequently in their vapour pressures. The boiling point of butane is considerably higher than that of propane, the pressure therefore at which it is available in the container is lower.

For industrial use, butane usually requires a vaporizer because of its low pressure, but during the warmer weather the gas may be drawn direct from the storage tank, except where large yields of gas are required.

The vaporizer is a simple heat exchanger using steam or hot water to supply the latent heat of vaporization. The quantity of heat required to vaporize butane and propane is relatively low,

1 *Modern batch-type heat-treatment furnace with endothermic generator*

(*d*) The gas shall not contain more than 2·0 grains of mercaptan sulphur per 100 cu ft at S T P (sat) as determined by the current edition of I P Method 104.

(*e*) The hydrogen sulphide content shall be nil as indicated by moist lead acetate paper exposed to the gas.

(*f*) The odour of the gas shall be distinctive, unpleasant, and non-persistent and shall indicate the presence of gas down to concentrations in air of one-fifth the lower limit of inflammability.

Commercial propane

Commercial propane shall be a hydrocarbon mixture consisting predominately of propane and/or propene. It shall not contain harmful quantities of toxic or nauseating substances and shall be free from mechanically entrained water. It shall have the following composition and properties:

(*a*) The total content of C_1 hydrocarbons shall not exceed 0·1 moles %.

(*b*) The total content of C_2 hydrocarbons shall not exceed 3·0 moles %.

(*c*) The total content of C_4 and higher hydro-

TABLE I—*Average properties of commercial butane and commercial propane*

	Commercial butane	Commercial propane
Specific gravity of liquid at 60°F	0·570—0·580	0·500—0·510
Specific gravity of gas compared with air at S T P	1·90—2·10	1·40—1·55
Latent heat of vaporization at 60°F	160 B Th U/lb	154 B Th U/lb
Volume of gas per 1 lb of liquid at S T P	6·5—6·9 cu ft	8·6—8·7 cu ft
Specific heat of liquid	0·57 B Th U/lb/°F	0·60 B Th U/lb/°F
Limits of inflammability (% gas and air to form a combustible mixture)	Upper 9·0% Lower 1·5%	Upper 10·0% Lower 2·0%
Gross calorific value	21,300 B Th U/lb 3,200 B Th U/cu ft	21,500 B Th U/lb 2,450 B Th U/cu ft
Sulphur content	Negligible to 0·01% wt	Negligible to 0·01% wt
Boiling point	20°F	−40°F
Imp gal/ton 60°F	385	448
Therms/ton	477	480

	Temp	P S I A	P S I A
Vapour pressure at (for products of the maximum specified vapour pressure)	−40°F	—	15
	0°F	—	35
	32°F	20	75
	100°F	73	225
	113°F	100	270
Air required for combustion (cu ft air to burn 1 cu ft gas)		31	24
Ratio of gas volume to liquid volume at S T P		240	275

designed vehicles in full 4½- and 9-ton loads in the case of commercial butane and 4- and 8-ton loads for commercial propane. These deliveries are made into customers' own storage. It is recommended that storage capacity should be a minimum of three weeks' supply at maximum consumption, and the smallest size of tank into which bulk deliveries can be made is 5 tons. Should the consumption of L P gas not warrant the installation of bulk storage, commercial butane and commercial propane can be supplied in transportable tanks of 1-ton capacity, these being filled at the appropriate refinery. For the smaller industrial applications both grades are available in various sizes of portable containers, which can be coupled in multi-container assemblies if required.

Handling and storing

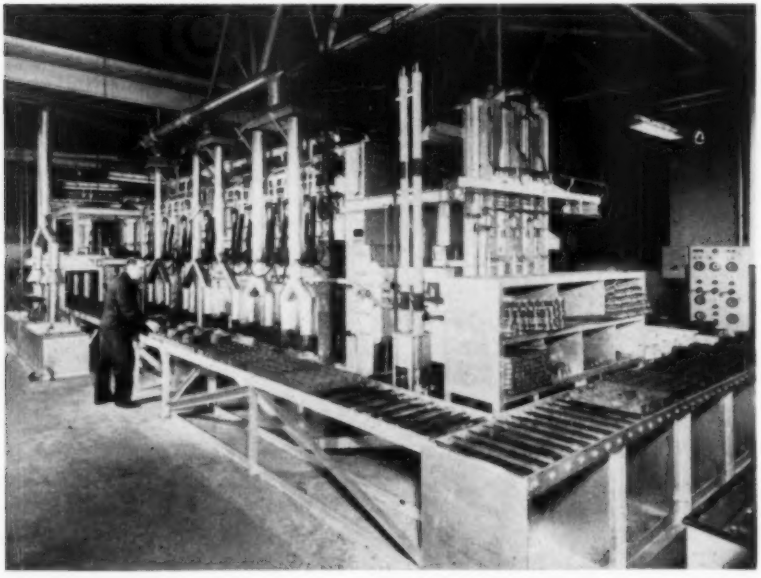
Many years of experience have shown that L P gases may be handled and stored with complete safety if proper engineering standards are followed, and if the same precautions with regard to the tanks are taken as in the handling of other fuel gases.

Bulk installations in this country have been installed in accordance with the latest American practice, as laid down in the National Fire Precaution Association's pamphlet No 58, but are subject to overall approval by H M Factories Department. In this pamphlet the following minimum distances between storage tanks and occupied buildings and between individual tanks are laid down as follows:

Capacity of tanks	Minimum distances	
	From buildings to tanks	Between tanks
Up to 1 ton	10 ft	3 ft
5 tons and over ..	50 ft	5 ft

Tanks for the storage of L P gases should be manufactured generally in accordance with the British Standards Specification No 1500, ' Fusion Welded Unfired Pressure Vessels.' Insurers may insist, however, that additional precautions laid down by the Associated Offices Technical Committee's rules should be followed, this committee representing five of the leading engineering insurance companies in the U K ; or to a similar code as laid down by the American Petroleum Institute and the American Society of Mechanical Engineers. Tanks are equipped with a number of safety devices such as pressure relief valves, excess flow valves and the means of assessing the contents.

Portable containers and small tanks are designed for a maximum working pressure equal to the maximum vapour pressure of the L P gas at 113°F regarded as the maximum summer sun temperature, namely 255 lb/sq in. gauge for commercial propane and 85 lb/sq in. gauge for commercial butane. In the case of large tanks it is recognized that the contents are unlikely to reach a temperature of 113°F in sunlight, and the designed maximum working pressure for vessels of 4 tons and over is



5 *Large continuous gas carburizing furnace (E N V Engineering Co Ltd)*

being approximately 160 and 154 B Th U/lb respectively.

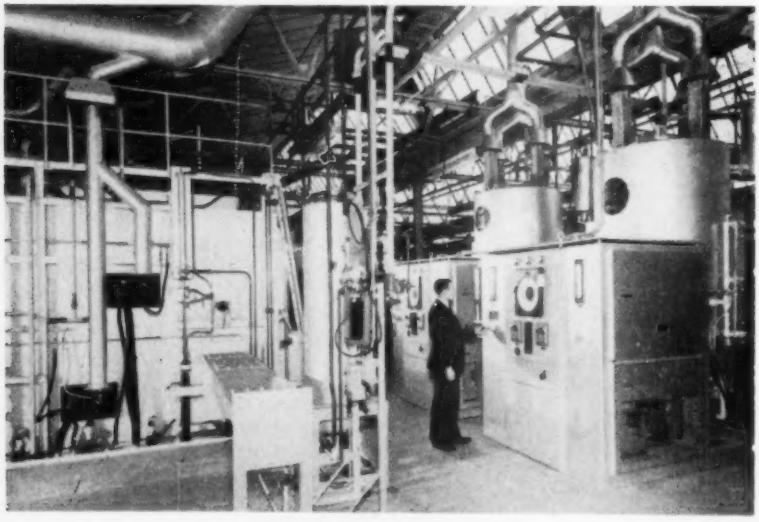
Propane will generally vaporize in the storage vessel except when the demand for gas is so large that the cooling effect of vaporization in the storage vessel reduces the vapour pressure to a point below that at which the gas is required.

The necessity for a vaporizer when using butane or propane is governed by the rapidity with which the latent heat of vaporization can be supplied and transmitted to the liquid, and whether or not it is required can be calculated from such factors as maximum gas offtake, size of vessel, minimum amount of liquid gas in storage, and pressure required at the plant.

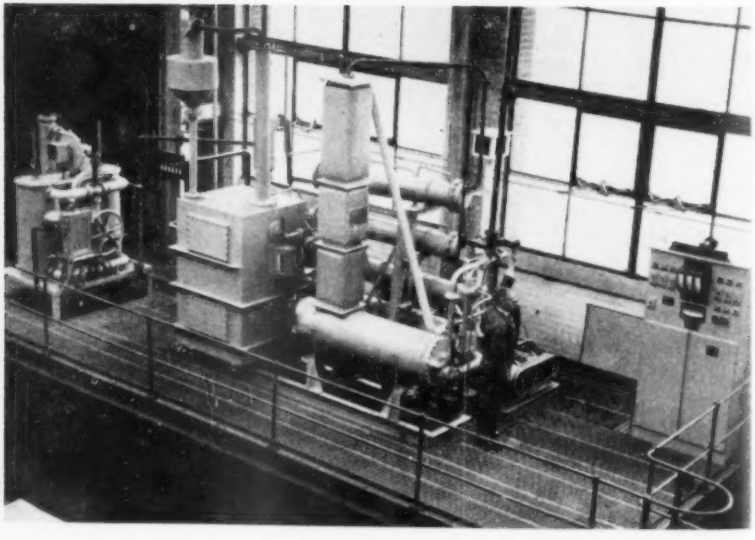
The ability to vaporize butane as described above means that, except where high pressures ($2\frac{1}{2}$ to 3 atm) are required, butane or propane can be regarded as interchangeable from the application and combustion point of view.

Supplies and storage

As mentioned earlier in this article, L P gases are now delivered throughout Great Britain in specially



3 LEFT *Endothermic gas generators producing protective atmospheres for gas carburizing (E N V Engineering Co Ltd)*



4 RIGHT *Typical 2,000 cu ft/h Hi-nitrogen plant burning propane (Incandescent Heat Co Ltd)*

Operational research in industry

W. E. DUCKWORTH, M A, A I M, A I S

In the leading article of our issue of November, 1957, we appealed to readers for information of any articles explaining in non-specialized language how operational research workers undertook their various tasks. As a result, we have received two such contributions from operational research scientists working in the metallurgical industries. Mr Duckworth, the author of the first of these articles, is a metallurgist who has specialized in operational research methods and is manager of the Operations Research Department of the Glacier Metal Co Ltd. The first part of his article appears below and will be concluded next month. It will be followed by a contribution describing operational research at I C I Metals Ltd

OPERATIONAL RESEARCH (O-R) has been described by Arthur Clarke as 'the art of winning wars without actually fighting.' This definition has the merit of brevity and wit but does not, alas, contain enough truth for general acceptance.

In a recent book[1] the following definition has been suggested: 'O-R is the application of scientific methods, techniques and tools to problems involving the operations of a system so as to provide those in control of the system with optimum solutions to the problems.'

The key to this definition is the phrase 'optimal solution to the problems . . . involving the operations of a system.' In O-R work the system is taken for granted, the problem is to do one's best with it. In the famous wartime example of how best to destroy a submarine by dropping a depth charge from an aeroplane the O-R team accepted that the choice of an aeroplane and the use of a depth charge was fixed and set to work to optimize the method. It may be that some device other than a depth charge would have been more effective, but it was the task of other branches of research to examine such alternatives.

If you call in an operational-research worker to solve a problem in, say, the production control of a nitriding shop he does not suggest that your difficulties would be reduced if you changed over to gas carburizing. He has a right to expect, although he will probably want to satisfy himself on the point first, that you wish to produce a metal surface with a given hardness and that for your own application you are persuaded that nitriding is the best solution. If there are still some doubts on this score then metallurgical research is required before operational research can be useful.

Well, then, given that you have a system which is sound in principle and worth while operating, what is it that operational research can do for it? To answer this question it is probably useful to go a little into the history of operational research. Although (if one really tried) one could probably discover elements of O-R in the military work of Archimedes and some of the scientists who worked for Napoleon and certainly of some of the scientists in World War I, it was really in World War II that it began to establish itself as a separate discipline.

When the British Government, anxious not to waste resources in the years of total war following Dunkirk, banded together groups of scientists to assist field commanders in solving strategic and tactical problems, it caused biologists to examine problems in electronics, physicists to observe movements of men rather than movements of molecules, mathematicians to examine how probability theory could influence men's survival and chemists to study equilibria in systems other than chemical ones.

From all this work there arose the realization that techniques for studying systems in one discipline could be used with success in solving problems in systems outside that discipline. Communication within a command or a unit exhibited symptoms similar to those which had been studied in telephone circuits. Control of an operation involving men and machines needed the same requirements for its success as did the servo-mechanism of an aircraft. The delays in unloading ships at ports were similar to the delays in waiting for calls at telephone exchanges, which had been studied for many years.

All these and other examples showed that there was a need for a technology in the study of systems which could draw from experience in the biological, physical, chemical and engineering sciences and utilize this experience in a wider sphere. This common technology is the technology of operational research, the science of systems optimization.

that of the maximum vapour pressure at 100°F, namely 210°F/sq in. gauge and 70°F/sq in. gauge for commercial propane and commercial butane respectively.

Containers used for the storage of L P gases may be filled only to the extent laid down by the 'Filling Ratio.' This is defined in British Standards Specification No 1736 as 'the ratio of the weight of liquefiable gas passed into the container to the water capacity of the container,' water capacity being defined as 'the weight of water required to fill the container at 15°C.' The filling ratio varies according to the specific gravity of the liquefied gas concerned, and is for current makes of commercial propane 0·44 and for commercial butane 0·50.

Before considering the various applications of L P gases it should be mentioned that commercial butane and commercial propane should not be considered as a cheap source of heat. They have, however, a great value in those industrial fields where a fuel of high purity, constant quality and high calorific value is required, or where the almost complete absence of sulphur is essential.

Metallurgical uses

The potential field for the application of L P gases to industrial purposes is almost unlimited. Their outlets may be looked for in firing metallurgical furnaces, and many applications such as gas carburizing, and the production of protective atmospheres for heat-treatment processes in which L P gases are pre-eminent.

One of the biggest outlets in the metallurgical field for L P gases is the production of protective atmospheres. Most metals when heated in air to the temperatures required for heat treatment undergo some deterioration of the surface due to oxidation and other reactions. An inert protective atmosphere overcomes the influence of air, and L P gases provide a ready means of producing these atmospheres.

Two types are in common use, made respectively by exothermic and endothermic reactions and are, therefore, commonly termed exothermic and endothermic gases. The former is made by the controlled burning of L P gases with limited air in the range 55% to 100% of the theoretical air required for combustion. The resulting gas consists of a mixture of nitrogen, hydrogen, carbon monoxide, carbon dioxide and water vapour; the last two constituents are in some cases removed before the gas is used.

Endothermic gas is made over a catalyst in a refractory reaction chamber heated externally, L P gases being supplied to it with a small amount of air—about 25% to 40% of the theoretical combustion requirements. The gas produced provides a more reducing atmosphere, being considerably higher in hydrogen and carbon monoxide. The choice of these gases depends on the metallurgical processes to be carried out.

The production of protective atmospheres from a hydrocarbon gas of constant composition and low sulphur content offers great advantages. Atmospheres generated from L P gases are substantially suitable for the bright annealing of copper, brass, and nickel, and it is expected that they will be used to an increasing extent for heat-treatment work in general.

Fine limits

It has been proved quite conclusively in practice that protective atmospheres are not only produced efficiently with L P gases, and with the minimum of supervision, but also to within very fine limits of composition and dewpoint. Furthermore, the high hydrogen content of L P gases results in appreciably greater volumes of protective atmospheres being produced than from manufactured gas. Many plants for producing protective atmospheres from L P gases have been installed in this country, and the largest continuous gas carburizing furnaces built to date are using L P gases for producing the required endothermic gas and for supplying the required carbon potential.

This use of L P gases in gas carburizing is a rapidly growing application, displacing the older and much less efficient pack carburizing and case hardening processes.

All types of direct and indirect-fired furnaces can be used with liquefied gas, in many cases little or no modification being required. They are particularly attractive for direct firing when a neutral or reducing atmosphere is required, and are easier to control than other fuel gases.

Radiant heating

Heating with radiant panels fired by L P gases is becoming increasingly popular for the heating of large uninsulated buildings where doors are continually being left open, and where a large number of air changes are taking place. Buildings of this description are found, for example, on large airfields where other sources of gaseous fuel are not available. Radiant panels are also used to a large extent in drying ovens.

Even though the use of L P gases in industry is still in its early stages, the outlets are already numerous. Plans will be completed in the very near future whereby these fuels will play a major part in other production processes including the heat treatment of high-nickel alloys.

assertion that steel *B* is harder than *A* than was the case when the data could not be so arranged.

Steel *A*	Steel *B*
440	450
480	490
450	460
470	480
460	470
450	460
460	470

This principle of pairing off observations was used in an operational research evaluation of the suitability of different bearing materials in the big ends of internal combustion engines.[2]

The method of pairing off was to test (in the same engine at the same time) both the materials which were being compared. The advantage of this technique is shown in the figures given below for the amount of crankshaft wear caused by two typical materials in eight separate tests.

	Bearing material *A*	Bearing material *B*
Test No.	Crankshaft wear $\times 10^{-4}$ in.	Crankshaft wear $\times 10^{-4}$ in.
1	4.5	5.5
2	6.0	8.2
3	4.5	5.5
4	4.3	6.8
5	1.5	1.8
6	2.0	3.0
7	4.5	4.7
8	1.3	2.0

It can be seen that, although the amount of crankshaft wear varied by a factor of five between tests, an amount of variation not uncommon in wear tests, bearing material *B* caused consistently more wear than material *A*. It could thus be stated not only that material *B* was worse than material *A* but also a numerical estimate of the difference between them could be given with greater accuracy than if the materials had been tested independently.

This is a simple example, but many wear investigations have failed to yield useful results because the materials were tested independently and the variation between tests was so great as to make it very difficult to discriminate between the materials. By making use of statistical planning and comparing materials in pairs within tests the relative behaviour of big-end bearing materials has been compared with greater accuracy than hitherto.[3]

Many other examples exist in the literature[4, 5, 6, 7, 8] of how mathematical statistical methods can be used in the metallurgical field, but sufficient has been said to illustrate their value in operational research work where the data can be subject to large random variations and where both the analysis and the collection of the information need careful planning.

Linear programming

This is a technique which can be used in a situation where one has several products which can be made on each of several different machines and one wants a programme to decide which product shall be made on which machine in order to maximize output or minimize cost or satisfy some other criterion of efficiency. For example, in a forging shop one may have a mixture of old and new presses with different output rates and different costs. If there is a variety of jobs to be handled on these presses then the number of ways in which these jobs can be arranged may be enormous. For example, with 20 jobs to be arranged between 5 presses the total number of possible arrangements is 265,650. Not all of these will be worthy of consideration, of course. Many combinations involving an excessive loading of jobs on to one press can be rejected from the calculation, but this still leaves a large number of possibilities to be considered by the scheduling officer.

It is well known, in fact, that in this kind of situation the scheduling officer's job is a very skilled one and is usually handled by men with long experience who have evolved some very adequate rules for deciding upon the optimum arrangement.

Several other problems fall into this same category. Slitting paper or sheet steel from the production widths down into the widths ordered by customers is one example which has been successfully tackled. Deciding which goods to send from which warehouse to which customer or which tankers to send from which oil supply to which refineries are examples of the so-called 'transportation problem' of linear programming which are in use. In cases where there is a choice of resources to be deployed to achieve a variety of different objects, linear programming can usually be employed to give the optimal solution with the minimum of calculation.

A typical example which is in daily use at the Glacier Metal Co Ltd is the method of deciding which of several batches of whitemetal recovered from the manufacturing operations in which surplus whitemetal is machined from the cast bearings shall be used in making up fresh metal required by the foundry. Due to contamination and such effects as slight segregation, the composition of the recovered whitemetal differs from that of the required specification. It cannot therefore be used again directly but must either be sold or mixed with other metal to restore the correct composition.

If the metal is sold there is a book loss, because the price given is about 95% of the value of the tin in the alloy; the value of the copper and antimony are ignored. If the metal is kept for remixing

Development of techniques

The work of the early teams of operational research workers resulted in the development of certain techniques which did not belong to any of the individual sciences included in the team but which were a compound of the methods used by the various scientists in tackling the problems. Many of these techniques derived from mathematical statistics, which is still one of the most powerful tools in the O-R approach. This is necessarily so, because one common property of industrial systems is their variability and mathematical statistics is the method of handling the problem of variability. Other techniques which have been developed are linear programming, queueing theory, Monte Carlo methods, stock and production control models, decision functions and game theory, and cybernetics.

The purpose of this paper is to describe these techniques, as far as possible in non-mathematical language, and to discuss the results of applying these O-R methods to solving problems in a metallurgical-engineering firm of some 3,000 employees. From this it is hoped will emerge a picture of the problems with which operational research can deal, using these techniques and others which are developed as the need arises.

Mathematical statistics

Most of us are familiar with the ideas of probability. In tossing coins one expects heads and tails to occur with equal frequency so we say that the probability of a head or a tail is 1/2. In throwing an ordinary dice we can see that the chance of getting any particular number at the first throw is 1 in 6. If a penny always came down heads or a dice always came down with the five uppermost it would not take many throws before we began to suspect that all was not as it should be.

We would probably doubt the genuineness of the penny after five heads had occurred in the first five throws. Calculation shows that this sequence of heads could occur *by chance* once in thirty-two times, so it is not completely out of the question that the penny is unbiased. A probability of 1/32 is small enough, however, to make us suspicious. If we threw the penny for another five times and had a further five heads then we would have no doubt that the penny was biased, because 10 heads in a row only occur by chance 1 in 1,024 times and we all know from our experience with football pools that this kind of chance event does not happen to us, because these odds are similar to those of winning a worth-while dividend in any one year.

Mathematical statistics provide a means of calculating the probability of chance events in situations much more complicated than those of tossing pennies or throwing dice.

These calculations enable the O-R worker to say whether the result obtained in an experiment really shows that things have been changed or whether what was thought to be an important result could actually have occurred by chance.

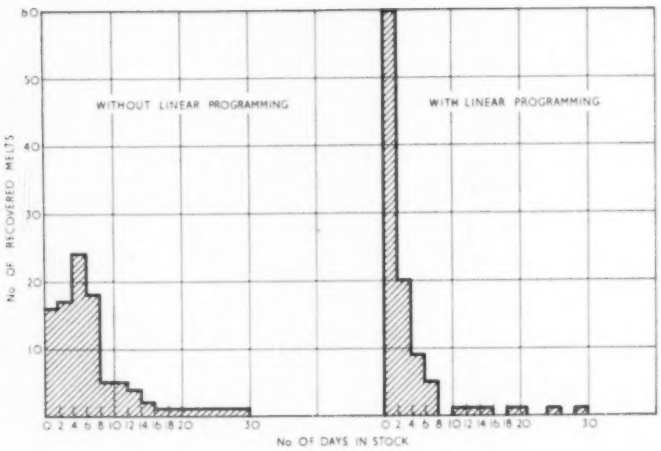
The following example illustrates this. Suppose an experiment on the hardening of two steels had given the following results:

	Steel *A* Hardness VPN	Steel *B* Hardness VPN
	440	460
	480	450
	450	470
	470	460
	460	470
	450	480
	460	490
Average	460	470

At first sight it looks as though the two steels have substantially the same hardness and yet steel *B* has the higher average. Even though the difference in average is small it might be important. The methods of mathematical statistics can state in precise terms the probability of obtaining such a difference by chance if there was in fact no difference between the two steels and thus they assist in making the decision whether to accept the difference as real or illusory. If it is considered that there is not enough evidence to decide one way or the other then statistical methods can also help one to calculate how many more tests to carry out in order to reach a decision with a known degree of certainty.

In the above example the probability that the observed difference was due to chance is about 1 in 6, so that not much confidence could be placed in the assertion that steel *B* was harder than steel *A*. If 25 tests were carried out on each steel, however, and the difference of 10 points still persisted, the probability that the difference was due to chance would then only be 1 in 20 and the statement that steel *B* was harder than steel *A* could be made with much more confidence.

Statistical methods can also guide the planning of experiments so that the optimum use is made of whatever data is obtained. The general principle of such techniques is to arrange that the data can be paired off in such a way that differences between the observations are emphasized. For instance, if the above data on hardness had been obtained so that the results for *A* and *B* could be compared pair by pair as shown below, it will be seen that in every case steel *B* has a higher hardness than steel *A* and more confidence can be placed in the


WITHOUT LINEAR PROGRAMMING
WITH LINEAR PROGRAMMING
No OF RECOVERED MELTS
No OF DAYS IN STOCK
0 2 4 6 8 10 12 14 16 18 20 30
0 2 4 6 8 10 12 14 16 18 20 30

1 *Distribution of recovered melts by number of days in stock*

but cannot be used for a long time, then a substantial amount of available capital may be tied up and additional storage costs incurred.

There are usually about 20 batches of recovered metal available for making up fresh metal required by the foundry and so there is the problem of which melts to choose and in which proportion to use them. This problem used to be tackled by an experienced chemist who spent nearly half his working day making the decisions. It is now solved by linear programming by a girl computer working at a desk calculating machine for about two hours a day.[9]

No great savings were experienced initially when the linear programming method was introduced. The utilization of recovery melts was increased, however, by about 4% and stock turnover was much more rapid because it was possible to explore the possibilities of all the available batches, whereas the chemist with his slide rule tended to concentrate on the more obvious melts and the less amenable ones therefore accumulated. This reduction in stock is shown in fig 1.

The chemist had been very good at his job and built up a good deal of experience over the years, so no spectacular savings occurred at first. In the last two years the superiority of linear programming over the old method has, however, been clearly demonstrated. The system is very flexible and can adjust itself to changes in supply and demand very rapidly, whereas the previous technique, being necessarily built up on experience, was slow to change. In the motor industry recession of 1956 there was no building up of recovered metal stocks when the ratio of supply to demand changed. The calculations took the change into account and the increased proportion of recovered melts was immediately utilized, whereas in previous recessions quite high stocks had been built up before this change in conditions was allowed for in the calculations.

The linear programming method has enabled a bird's-eye view of the process to be obtained. It is now clear which type of recovery melt can be used and which cannot. The latter are not allowed to remain in stock, but are recommended for sale immediately. Certain restrictions on the use of recovered melts due to specification limitations were recognized and a recommendation to a B S I Committee arising from this may well bear fruit.

The principle of linear programming can be illustrated with reference to the example of choosing the proportions of several alloys required to make up a new alloy economically. Suppose we have two recovered melts available with the following compositions:

Melt 1	*Melt* 2
2 parts copper	1 part copper
1 part nickel	3 parts nickel

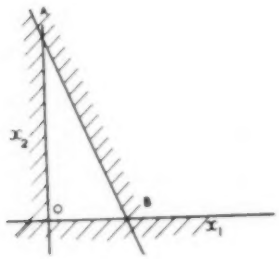
There are 7 lb of the first melt available and 6 lb of the second and we want to combine suitable proportions to make 10 lb of a 50/50 copper nickel alloy. Let us further assume that if we use the first alloy instead of pure copper or pure nickel we save 5d/lb and if we use the second alloy we save 10d/lb. The problem is to use the two alloys in the proportion which will maximize our saving.

We want 10 lb of a 50/50 Cu/Ni alloy, so we need 5 lb copper and 5 lb nickel. If we let x_1 be the weight of the first alloy that we use, then the weight of copper it will contribute is $\frac{2}{3} x_1$. Similarly if x_2 is the weight of the second alloy used, then the weight of copper it will contribute is $\frac{1}{4} x_2$.

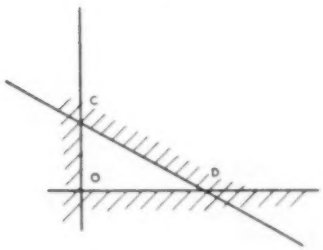
If z_1 is the weight of fresh copper we have to add, then the total weight of copper we use is

$$\tfrac{2}{3}x_1 + \tfrac{1}{4}x_2 + z_1$$

2



3



But in our final alloy we must have 5 lb of copper, so therefore we have our first equation,

$$\tfrac{2}{3}x_1 + \tfrac{1}{4}x_2 + z_1 = 5$$

Similarly for nickel,

$$\tfrac{1}{3}x_1 + \tfrac{3}{4}x_2 + z_2 = 5$$

where z_2 is the amount of fresh nickel added.

In addition we know that x_1 cannot exceed 7 lb and x_2 cannot exceed 6 lb. To obtain the greatest saving (5d on x, and 10d on x_2) we must maximize

$$5x_1 + 10x_2$$

This is the typical formulation of a linear programming problem and in this case we can solve it graphically.

The equation $\tfrac{2}{3}x_1 + \tfrac{1}{4}x_2 + z_1 = 5$ describes the unshaded region in fig 2.

The line AB is the equation $\tfrac{2}{3}x_1 + \tfrac{1}{4}x_2 = 5$ and this represents the upper limit of the copper content required, because we do not need more than 5 lb of copper. The region on the right-hand side of AB is therefore shaded, showing that we do not want to consider any points in this region. Similarly the parts below the line x_1 and to the left of the line x_2 are shaded because these regions represent *negative* values of x_1 and x_2 which we are certainly not interested in.

So the solution we want is somewhere in the triangle OAB. A similar triangle can be constructed for the nickel equation

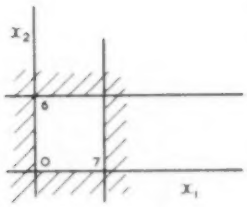
$$\tfrac{1}{3}x_1 + \tfrac{3}{4}x_2 + z_2 = 5$$

This is shown in fig 3, where CD is the line

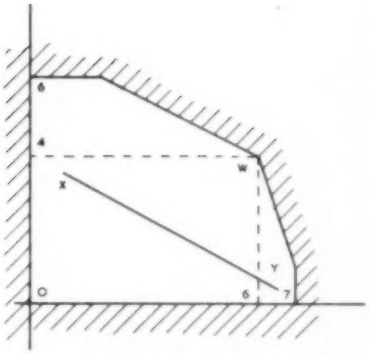
$$\tfrac{1}{3}x_1 + \tfrac{3}{4}x_2 = 5$$

The limitation that x_1 cannot be more than 7 and

4



5



x_2 cannot be more than 6 is shown in fig 4. The solution to our problem must therefore lie within the region common to figs 2, 3 and 4. This is shown in fig 5. Within that region we want to make

$$5x_1 + 10x_2 \text{ a maximum}$$

The line XY is a line with the equation

$$5x_1 + 10x_2 = \text{a constant}$$

We want to make this constant as large as possible, so we move the line to the right as far as we can while still remaining with the area where we know the solution must lie. The furthest we can go is to the point W which therefore represents the solution.

It can be seen that the solution is to use 6 lb of x_1 (alloy 1) and 4 lb of x_2 (alloy 2). No fresh copper or nickel is needed.

In actual linear programming problems there are more than two alternatives to consider and so the problem cannot usually be illustrated in two dimensions as this one can. To illustrate more complex problems would involve n-dimensional geometry. Relatively simple computing techniques have been evolved for these complex problems.

This example illustrates the technique, however, and a little study of fig 5 will show how altering the conditions alters the solution. If we make the amount of alloy 1 available less than 6 lb, for instance, it means that all of x_1 will be used and some extra of x_2 will be required but that the saving will no longer be as great as with the first solution.

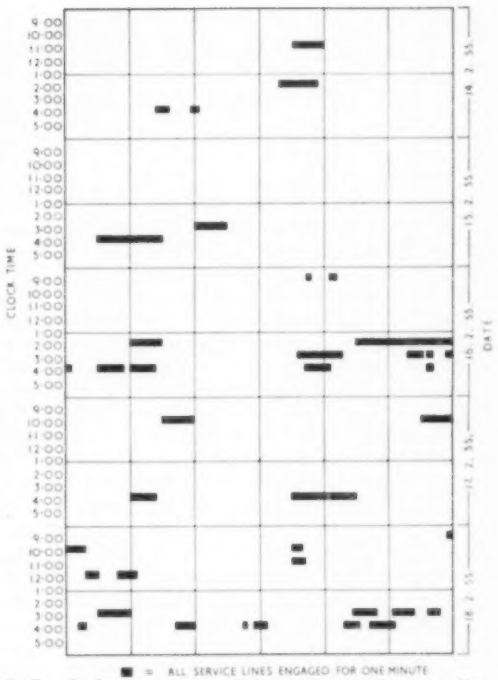
able cannot be expressed in mathematical form. This situation is solved by use of the so-called Monte Carlo methods. If this conjures up a picture of dice throwing and roulette wheel spinning it is meant to, because this is just how the O-R worker imitates the occurrence of chance events in the system he is studying.

As an example, suppose an event being observed has a probability of 1 in 6 of occurring in any half-hour period. Then, to build up a picture of how the event actually occurs in practice, we divide the working day into half-hour periods, throw a dice for each of these periods and each time a six comes uppermost (assuming the dice to be unbiased) record that the event has occurred. More complex probabilities can be imitated by means of other devices such as a table of random numbers and any system can be 'lived through' painlessly on a piece of paper and all the possible outcomes understood before the scheme is tried out in practice on the factory floor.

An example of this technique used at Glacier was to decide if a certain small factory had enough external telephone lines. There were in fact three lines and the factory manager became convinced that all three lines were in use so much that some customers, despairing of always hearing the engaged tone when they rang, would go elsewhere for their goods. For a period of a fortnight the telephone operator noted the amount of time that one, two and three lines were occupied and charts such as the one shown in fig 6 were produced, which showed the proportion of time all three lines were occupied. By choosing times at random at which customers might have telephoned, the O-R worker was able to record the proportion of times that the customer would have been connected immediately or, if he failed the first time, the probability that he was successful the second time. As can be seen from Table I, these probabilities were so high, nearly 100%, in fact, that the factory manager realized his original impressions were unfounded and that no extra telephone lines were needed.

It is common in O-R work to find that people's first impression of a problem is not the correct one and one of the tasks of an O-R worker is to understand for himself what the real problem is. A very useful technique for a manager who feels he has a congestion problem and which can help to establish if the problem is real or not, is the method of random observation studies[11], often called ratio delay or activity analysis by production engineers.

It may be reported, for example, that a certain machine in a factory is always a bottleneck. To establish the facts for himself the manager should merely note, each time he walks through the factory, which, except for meal times, will probably be at random intervals, whether the machine is in use or not. At the end of a fortnight when he consults his record, he may be surprised to find that the machine is by no means in constant use as had been claimed. Armed with such facts, collected without special effort, the manager will be on the way to sorting out the real problem. *to be continued*



6 *Graph showing time and duration of 'all service lines engaged'*

TABLE I *Chance of caller's acceptance in a single call during peak period 3—5 p m*

Date	Chance (in 100)
14th	97½
15th	87½
16th	78
17th	88
18th	77½
21st	100
22nd	80
23rd	96
24th	100
25th	100

It is this kind of consideration which enables linear programming to survey the problem in all its aspects and explore the consequences of alternative solutions.

Queueing theory and Monte Carlo methods

We are all familiar with queues. If too many people arrive at a shop in a given time then a queue forms. Most factories are operated on the principle of having queues so that work can be continually fed into a department without the periods of idle time which might ensue if there were no queues. In this case a queue is a good thing, it helps to assist in economic planning of the department's work. If the queue becomes too large, however, difficulties arise. The pace of work may be stepped up to reduce the queue and unless the increased pace is within the capacity of the department, efficiency may in fact fall, leading to the queue being lengthened rather than shortened.

Priorities may be resorted to, and this can be a very vicious move because the transfer of jobs to a higher place in the queue only results in the average waiting time of all remaining jobs increasing, which may increase the need for further priorities, and so a cycle of panic measures sets in.

For service-giving departments such as millwrights a queue of work can be a very inefficient thing to have. If too many machines are needing repair at the same time, the consequencies can be serious.

A mathematical theory of queues has been developed which enables operational research workers to calculate for any given situation what kind of queue will result and how long the items will have to wait before service. Certain conclusions of this theory are sufficiently concise to be worth stating here.

In the first place the probability of a queue varies more or less directly with the proportion of time that the service provided is going to be in demand. Thus, if a service is used to 80% of its capacity, the probability that there will be a queue is 8 out of 10, *i e* in 8 out of 10 calls on that service we shall have to wait before being served.

This is something that we all observe in practice. If we frequently visit a shop with several assistants and we find that we are always served immediately, then we notice that some of the assistants have no customers to see to. If, on the other hand we call in at a busy newsagents every morning and there is only one man serving behind the counter we almost invariably have to wait a while.

The meaning of this relationship between service capacity and queue probability is that if we carefully plan a service department so that it has just enough capacity to meet expected demand, then there will always be a queue and it will always keep on growing.

If, on the other hand, we want it to meet every demand almost immediately then we must expect it to spend about half its time in idleness. This explains the perpetual headache of the man in charge of such a department—how to arrange things so he can give a reasonable service and yet at the same time keep his men fully occupied. In this situation the man who keeps the odd painting job up his sleeve is not really making work for his men, he is ensuring that his department can give a good service and yet not appear to be over-staffed.

The other main conclusion which emerges from the theory of queues is that the more haphazard the arrivals the more likely there is to be a queue. This is because with haphazard arrivals a time may come when no demands are made for a long period. That time is irretrievably lost from the system and when subsequently a bunch of arrivals occurs there is no way of breaking up the *log* jam.

To ensure that reasonably rapid service can be provided, therefore, it is advisable to ensure that the service-giving department—or production unit—is only loaded, on average, to about 80% of its capacity and that the rate of demands on it are made as uniform as possible.

This is common sense, of course, and most managers do not need an operational research study to tell them this. There are many complex situations, however, in which we may wish to know precisely how long items may have to wait in a queue for a given service capacity so that we can decide whether to provide extra capacity, at extra cost, or let the items wait a little longer and risk the losses which may arise from giving a less satisfactory service.

Such an investigation was carried out at the Glacier Metal Co Ltd into one of the systems for quoting prices to customers.[10] The system was common to many such systems. The Sales Organization received the customers' enquiry, passed it to the production engineering department (P E D) who estimated what the part would cost to produce and then sent the estimate to the Sales Organization who quoted the customer a price. Because of congestion in the P E D estimating section it sometimes took several days for an estimate to be prepared. A study of this congestion, together with some reorganization in communications arranged by the Work Study Department, showed that by employing two extra estimators no estimate would take longer than four hours to complete. Sales Organization considered that it was necessary for them to have the estimates in four hours and so the recommendation was adopted.

Some queueing systems are so complicated as to defy mathematical analysis or else the data avail-

Surface finish

Metallurgical and mechanical aspects

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The various expressions used in the study of surface finish are described, together with the more important machine and material variables which affect them. Particular attention is paid to chip formation and its influence on surface finish. The effect of metallographic structure is examined at length owing to its bearing on the formation of built-up-edge. Investigations into the mechanism underlying the formation of 'smear metal' are described and the various means for its removal compared, the comparison including an examination of the effect of cold-working on surface finish. This article by Mr Lewis, Principal of the Technical College, West Bromwich, is concluded from last month's issue

STRAIN-HARDENABILITY It is essentially ductile materials which developed marked strain-hardenability during the cutting process that yield a type-3 chip, *i e* with a built-up-edge, and so lead to relatively poor surface finish. This aspect has been discussed at length.[32] There is no truly direct method of measurement of strain-hardenability and the index is usually by means of the Meyer exponent, n, determined experimentally from the Meyer hardness formula,[33] $L = ad^n$, n being the slope of the curve obtained by plotting indentation diameter against load. The value of n must be 2·0 or greater and, the higher its value, the greater the strain-hardenability of the metal. Apart from the recent doubts expressed above, the Meyer index and the coefficient of friction are generally regarded as the two basic mechanical variables exerting the greatest ultimate effect on surface finish.

Microstructure and material considerations Of recent years, consideration of the microstructure has received much attention with reference to the various aspects of machining, including surface finish. The simplest case is that of pure metals, most of which are comparatively soft and weak. Metallurgically, structure, as such, cannot affect the result, but certain improvements can be carried out with regard to surface finish, notably by increasing the hardness of the metal—achieved by decreasing the grain-size or by strain-hardening by cold-working (the latter remark refers to applied strain-hardening and not to the inherent strain-hardenability of the material). To assist improved finish, however, these material treatments should be accompanied by the two important machining considerations—as high a cutting speed as possible and a tool with a high degree of rake—as previously described.

An excellent example of the relation of optimum structure to the machining operation has been given in a comparison of turning and broaching.[34] Since broaching is inherently a low-speed operation, there is a greater tendency to form a built-up-edge. To counteract this tendency a harder structure is required for broaching and a high-carbon spheroidized steel is usually too soft to produce a satisfactory finish by this method. Some combination of sorbite and pearlite would undoubtedly be preferred. Indeed, it is now generally accepted that the structure or hardness of a material which is the best for one type of machining may not be the most desirable for some other operation.[35] A further example has been shown in the machining of gears[36]—a spheroidized structure was found to be the best structural condition for the roughing operation, but a lamellar structure was superior for the actual cutting of the teeth. In the case of medium-alloy steels, the balance between the variables—structure, finish and tool life—is sometimes best met by annealing to obtain a fully spheroidized structure for roughing, and so ensuring maximum life and machining speed, and then re-treating the steel to the lamellar pearlite condition in order to obtain optimum surface finish from the finishing operation.

The various groups of plain carbon and alloy steels require separate consideration. Thus, the low-carbon steels, *i e* those containing less than 0·2% carbon, behave similarly to pure metals. The amount of carbide present is, in any case, so small that its distribution is unimportant. The only

Uranium in Britain

The search for uranium by the Atomic Energy Division of the Geological Survey

THE PART PLAYED by the Atomic Energy Division of the Geological Survey in the search for uranium is little known because of the security measures that have applied until comparatively recently to information on the production of nuclear raw materials.

The Division, which is the youngest branch of the oldest organization now in the Department of Scientific and Industrial Research—the Geological Survey of Great Britain—was created during the second world war to investigate the exploitation and supply of uranium and other strategic materials. Since that time it has played an important part in bringing uranium properties into production and in organizing and stimulating the search for the raw materials of atomic energy in many of the countries of the Commonwealth. Close co-operation is maintained between the Division and the Atomic Energy Authority, on whose behalf the work is undertaken.

The Atomic Energy Division has grown to be a major branch of the Geological Survey and the assistance it can give ranges from radiometric assaying and the preparation of mineralogical reports to field surveys and the assessment of new discoveries of mineralization made by prospectors and mining companies. For example, in 1957, field investigations were carried out in the Union of South Africa, British Guiana, Jamaica, Sierra Leone, Bechuanaland, Ghana, Nigeria, Nyasaland, Southern Rhodesia and New Zealand, in addition to field work in Britain.

Air survey of Cornwall

Last year the Atomic Energy Division of the Geological Survey, acting on behalf of the Atomic Energy Authority, undertook an airborne radiometric survey of west and central Cornwall. Results of this survey have so far been interesting. Several of the anomalies recorded are sufficiently marked at surface to merit pitting, trenching and exploratory drilling to prove the extent of the mineralization underground. The area to be covered by airborne survey will be extended this year to cover the remainder of Cornwall, and much of Devon and Somerset. Any areas which seem to justify closer examination will be investigated by ground parties equipped with portable scintillation and Geiger-Müller counters.

In addition to this air reconnaissance survey, the Division is undertaking the examination of abandoned mine workings in Cornwall where small amounts of uranium are known to occur. Only surface, or near surface, examination has hitherto been possible, but reconnaissance drilling has recently started and will continue on an increased scale during the summer season. The division may later expand its survey to cover other areas in which uranium mineralization might occur; for example, north and central Wales, north England and the southern uplands of Scotland.

Field work of this type is of little value without research facilities behind it. Behind the scenes, in the division's laboratories, the potential ores are examined in detail—a less spectacular yet vitally important task. Radioactive mineral specimens found in the field—either by the Geological Survey's own geologists, by other geological surveys, by mining companies or by private prospectors—are studied by the most modern techniques, some of which have been developed by members of the division.

An indication of the complexity of the work undertaken may be obtained from the fact that there are over 100 known uranium-bearing minerals and over 50 thorium-bearing minerals. Thousands of samples are normally examined annually and, at the same time, a research programme is maintained which has enabled the division to make a considerable contribution to radiogeology in papers published, from time to time, in the bulletin of the Geological Survey and other scientific journals. Studies of world-wide importance have been made in the fields of mineralogy and ore genesis, autoradiograph techniques, ore mineral identification and the examination of radioactive minerals by X-ray methods.

Free assay service

To mining companies, private prospectors, including members of the public, the division provides on behalf of the Atomic Energy Authority a free assay service for material which is considered to be radioactive. The only proviso in accepting material is that full details of locality must be given. This information is, of course, treated as confidential.

An idea of the effort involved in the detailed examination of rock samples can best be seen by tracing one through the laboratories. When

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direct remedy for improving the finish of this group is generally by some form of cold-working, *e g* cold-rolling or cold-drawing, otherwise it is preferable to use a free-machining variety of the same carbon specification. In certain instances, however, the use of such material may be precluded on metallurgical grounds.

It is in the medium- and high-carbon steel groups that machining characteristics are influenced to a much greater extent by metallographic structure. It is advisable within certain limits to use as hard a metallographic structure as possible in order to minimize the possible formation and function of the built-up-edge. This requirement demands wide dispersion of carbide particles and a small mean ferrite path. Against this, on the other hand, it is preferable that the area occupied by carbides per unit area of surface be as small as possible (*i e* relatively few widely separated carbide areas of large size) if inferior wear performance of the tool from hard particles in the workpiece is to be avoided. Obviously, then, a compromise must be effected between these opposed requirements for carbide distribution and, it is suggested,[34] an optimum mean ferrite path must exist, shifting in the direction of a greater mean ferrite path as the carbon content of the steel increases. Thus, a pearlitic structure is usually selected for medium-carbon steels, changing to a spheroidized structure for the higher-carbon steels, but this generalization must be implemented by actual machining tests if the best combination of machining conditions (*i e* for output), tool wear and surface finish is to be effected. Much has been done in this direction of recent years and the outstanding contributions of the U S Air Force Machinability Project[37, 38] provide excellent guidance regarding the effect of microstructure on the various aspects of the machining process. Where difficulty arises, more especially with softer materials, assistance can be given by increasing the structure hardness through heat treatment, provided the improvement obtained is not offset by increased wear due to hard particles.

The question of grain-size may also be involved. It is generally accepted that small grain-size, while frequently leading to inferior tool life, usually results in improved surface finish, but recent German work[39] would appear to cast a degree of doubt on this general finding in the case of the turning of certain steels. Thus, unalloyed and chrome-manganese case-hardening steels showed their best surfaces in the coarse-grained ferritic, lamellar pearlitic structures, while heat-treated structures gave surface finishes nearly as good as (and, sometimes, better than) fine-grained ferritic, lamellar pearlitic structures. Soft, annealed forms did not depart from previously accepted views and, in all cases, produced poorer surfaces than did ferritic-pearlitic structures. A large-grained material would tend to split more readily along crystallographic planes than would a fine-grained material, but, as has been pointed out,[40] there is probably a limit to desirable grain-size from the standpoint of surface finish. In the case of the pearlitic steels, the size of the lamellar pearlite grains undoubtedly has an effect on ease of machining and the type of finish produced. As already pointed out, next to a heavily spheroidized condition, a wide lamellar structure affords the fewest points of contact between the highly abrasive carbides and the cutting point of the tool, but the lamellar structure provides better support for the ferrite than does the spheroidized structure (except, perhaps, in the case of a very high-carbon steel) and ensures—at any rate, when machining both low- and medium-carbon grades—a better degree of surface finish. It is generally considered that the benefits resulting from the support given to the ferrite by the lamellar structure are at a maximum when the carbon content is of the order of 0·5%. Of the forms of compromise mentioned above, probably the best structure is a mixture of lamellar and spheroidized pearlite.

A typical instance of the benefit afforded by control of structure was given in the machining of a molybdenum steel forging at the plant of the Dodge Division of the Chrysler Corporation, U S A.[41] Using high-powered lathes and carbide tools and heat-treating the blank to give a uniform structure of 75% ferrite and 25% pearlite (Brinell range, 160—196), it was found possible, in addition to marked operational improvements, to machine before regrinding 100 pieces having a surface finish of 150 micro-inches, compared with a former value of 300. However, when the carbon exceeds 0·6%, the fully spheroidized structure will afford ample support for the ferrite and so provide the best balance between surface and tool life. The compromise could be effected at somewhat lower carbon contents when carbide-forming elements, such as vanadium or chromium, are present, but the balance will be affected by the amount of such element present.

Alloying elements generally have an adverse effect on tool wear, since they form additional hard carbides and or go into solution to increase the matrix hardness. The first group, including chromium, molybdenum, tungsten, vanadium, etc., cause increase in ploughing-type wear through increase in hard particles. When the alloy content is appreciable, machining is preferably carried out on material in the fully spheroidized condition. Ploughing wear is also brought about by incorporation of the solution elements which increase the matrix hardness and also the tendency for the matrix material to strain-harden and increase the hardness and size of the built-up-edge, so increasing the difficulty with regard to

finish. The increased hardness of the matrix also causes increase in the transfer type of wear, *i e* the transfer of metal from the tool face to the chip at the breakdown of temperature welds, since the hardness values of both chip and tool will be more nearly equal. The superior performance of hardened and tempered structures is undoubtedly accounted for by the fineness and uniform distribution of structural constituents. The finish must be balanced with the tool life, however, if economic machining is to be effected. Thus, a low nickel-chromium-molybdenum steel showed superior finish in the hardened and tempered condition (much superior to the annealed condition), but by far the best tool life (high-speed steel tools) was obtained on the material in the spheroidized condition.[37] With reference to the type of wear, it is important to remember that most wear at low speeds is of the ploughing type, while both the ploughing and transfer types of wear can take place at high speeds.

Mention must also be made of those cases where an added element or an impurity goes into solution in the ferrite, but where the attendant hardening effect is accompanied by sufficient reduction in ductility that there will be less tendency for a built-up-edge to be formed. Where the consequent improvement in surface finish is more marked than is the increase in power consumed, due to the hardening effect, the steel can be considered as being freer-machining (not necessarily 'free-machining' in the generally accepted sense). The occasional claims that plain carbon steels of higher manganese content are freer-machining than resulphurized steels of similar carbon content, but having lower manganese, are attributed to this effect.[42] The relatively high hardness of the ferrite in the various brands of free-cutting steel has been shown to be due in part to the amounts of phosphorus and nitrogen in solid solution, but the amount of such solute is relatively low, although the modified ferrite work-hardens only slowly in ordinary types of low-carbon steel.

Austenitic materials show a marked strain-hardening tendency on machining, resulting in a very hard and large built-up-edge, with ploughing wear from pressure welds at low speeds, with attendant inferior finish, and transfer wear due to the formation of temperature welds, the strain-hardening increasing the hardness of the chip to that of the tool. Metallurgically, the work-hardening characteristic is modified to some extent by composition.[43] Work-hardening, in the case of these materials, is due to deformation which causes partial transformation of the austenite to ferrite and to the fact that the cold-worked chrome-nickel ferrites formed are harder than pure ferrites owing to solid solution strengthening.

When machining steels, therefore, conditions must be maintained whereby cold-working of the chips and the surface of the part is minimized.[44] It is essential that tools should be sharp and well polished and have large top-rake angles, consistent with reasonable tool life, in order to avoid excessive deformation and consequent hardening of the chips. Chip breakers assist in preventing the chips from scratching the work, while heavy cuts (preferably at low speeds) are desirable in order to remove the work-hardened skin left from previous operations.[45] Reductions in speed are to be preferred to reductions in feed if tool life is unsatisfactory. The ploughing wear trouble can be overcome to a great extent by application of a suitable cutting fluid, which also assists tool wear by decreasing the pressure-weld area and the extent and hardness of the built-up-edge.[34]

Most high-temperature (jet) materials result in even greater difficulties with regard to work-hardening and each material must be examined on its merits and, if necessary, a special machining technique evolved. Many such studies have already been carried out by the Curtiss-Wright Corporation and described in the U S A F Machinability Reports.[37, 38] The case of titanium and its alloys is of outstanding interest. From the data obtained, it would appear that titanium should cut 'more easily' than does steel, since the coefficient of friction is generally lower, so that no real difficulty should be experienced in obtaining a good surface finish; and shear strength and unit power are lower. Thus, neither work-hardening nor machining forces can explain the phenomenon of low tool life which attends the machining of most titanium alloys. It will be appreciated, of course, that the high-temperature alloys have much higher shear strengths, so that increased machining difficulties will generally arise.

Undoubtedly, one of the most ready means for obtaining good surface finish with ease of working is by the use of free-cutting materials, provided they can meet the necessary metallurgical requirement. In the case of steels, tool life is increased, surface finish is improved and the coefficient of friction and the power required are both reduced for a given set of cutting conditions when employing free-cutting stock. In addition to breaking up the continuity of the ferrite, manganese sulphide is believed to provide a lubricating effect, so reducing frictional heat (between chip and tool) and tool wear. By imparting anti-seizure properties to the steel, it also reduces the tendency to formation of a built-up-edge on the cutting point of the tool. Even a quite small increase in the sulphur content of low-sulphur steels enables an improved surface finish to be obtained and higher cutting speeds to be employed.

In the case of relatively brittle materials, such as cast iron, the nature and size of the micro-con-

stituents often has a direct bearing on the surface finish obtained. While there may be a certain amount of fragmentation by the cutting tool, it has been found[46] that surface finish is directly related to the size and number of free graphite particles, the finish improving with decreasing graphite size, but, it has been pointed out,[6] that irons with larger flakes frequently give rougher surfaces owing to the tearing out of particles in the neighbourhood of the flakes. Irons with somewhat lower carbon contents often provide a better surface finish. Graphite particles, whatever their size or form, lead to relative weakness of the metal in tension, so that the chips formed in the machining of grey iron are discontinuous. Surface finish must benefit, therefore, in that a built-up-edge is not readily formed, although this may be due in part to a certain lubricating effect of the graphite.

Very recent work[47] gives a comprehensive survey of the factors affecting the surface finish of cast iron. While the quality of surface finish is shown to be dependent on machining conditions, tool geometry, the setting up and condition of the machine and the type of cast iron being cut, the graphite present, while definitely influencing surface finish in the manner described, has a much greater influence on the ' appearance ' of the surface. It is contended that the presence of the graphite in the surface tends to make it appear grey and thus less smooth than it actually is. In some machining operations, portions of the graphite may be pulled out of the surface of certain irons, leaving microscopic pits. The graphite in annealed irons (with a matrix of ferrite) is more likely to be pulled out of the surface. Apart from the size and shape of the graphite flakes, the surface finish is influenced by the matrix microstructure. A better finish will be obtained with finer flakes or nodular graphite in a matrix of fine pearlite. Free carbides are, of course, most undesirable, while, in commercial irons, the existence of the hard phosphorus-bearing constituent, steadite, can lead to tool-life and surface-finish troubles, but usually when present to an amount equivalent to a phosphorus content of 1% or more.

The recent investigation just mentioned[47] also showed that surface finish is improved with increased cutting speed and by using a light feed and shallow depth of cut, the quality of finish being more sensitive to the former. Dulling of the tool appears to act beneficially or adversely, depending on circumstances. Thus, if dulling results in a land on the end of the cutting tool which is generating the work surface, the finish may actually improve. Also, the nose radius may be increased, with the accompanying tendency for improved surface finish, as already explained.

Effect of the cutting tool While it would generally be agreed that the surface finish obtained in the machining of any one material would be progressively improved on changing from carbon steel to high-speed steel to cast non-ferrous alloy and finally to a sintered-carbide tool (in that order), the result would be due almost entirely to the increasingly higher cutting speeds which become available in changing from the first to the last group. If the same cutting speed could be used for all types, very little difference in the surface finish would be observed. Indeed, if for some reason a comparatively low cutting speed had to be used in the cutting of steel, the carbide tool would almost certainly not show the best performance by comparison due, if the speed were sufficiently low, to abrasion, or possibly at slightly higher speeds to a tendency for the carbide to weld to the metal. A high-speed steel tool has been found not unusually to have a greater tool life than has a normally equivalent carbide tool when operating at less than 50 surface ft min.[34] Consequently, tools which are required to work at characteristically low cutting speeds are generally made from high-speed steel. In the majority of cases, however, relatively high cutting speeds are called for and here the performance of cemented carbide tools is outstanding, and especially so in the case of hardened stock. Steels of high hardness give excellent finish on machining, but only as long as the tool remains sharp, so that, if the potential improvement in surface finish is to be capitalized, and particularly in the case of those materials which undergo considerable work-hardening on machining, it is essential that the tool is of material which does not readily abrade.

Although little or no change in finish is noted between the performance of the above-mentioned tools at any one sensibly selected speed, a diamond tool will usually give a better finish at the same speed owing to the low friction developing between the metal and the tool with, in consequence, a lesser tendency to the production of a built-up-edge.[20]

Surface action—' smear metal '

The above machining and material considerations can be regarded in the main as having a direct bearing on surface quality. There are, however, certain more or less indirect considerations which must be taken into account, and these are mainly metallurgical.

As is well known, Beilby[48] developed a theory that the polishing operation results, especially in the case of plastic materials, in a surface layer of metal being transferred over the surface. This ' smear metal ' was considered by Beilby to be amorphous or, at any rate, non-crystalline. The existence of such a layer is undoubted, but there has been much discussion concerning its nature. Bragg,[49] for example, maintained that an amorphous metallic film, if it exists at all, would be extremely short-lived in that state. This view is certainly supported by

electron-diffraction investigations in which there is fairly general agreement that the grain formation of the metal below the surface is deformed and fragmented for an appreciable depth. It may well be, however, that this layer or band is partly independent of the layer of pseudo-amorphous metal created in preparing the surface. The results of Wulff[50] are of importance in this respect. It is unfortunate that this work, published on a restricted basis during the last war, has not received the attention which it undoubtedly deserves.

Wulff's aim was to ascertain the depth and nature of the deformation induced by a variety of surface-finishing processes, his means of examination being electron diffraction, metallography and corrosion testing. Some of the views expressed on the last aspect call for remark, and especially with reference to the material used, namely, 18/8 chrome-nickel stainless steel (analysis not stated), in which a coarse-grained austenitic structure had been developed by annealing.

For the electron-diffraction studies, the methods of surface preparation used were fine grinding, wet grinding, cold reduction, honing, sanding, lapping, super-finishing and metallographic polish—it had previously been shown[51] that the last method of finish can be studied by reflected electron-diffraction methods. In order to determine the depths of transformed layers, measured amounts of metal were removed in successive stages by controlled electrolytic etching in 10% oxalic acid. The amounts removed from the surfaces were equivalent to thicknesses from 30—100Å. It is of interest to note that this technique did not alter the root-mean-square profile of the surface, although microscopic examination showed that etching had changed the true profile.

Diffraction results were recorded schematically with reference to structure, each sample giving a profilometer reading of from 1·4—2·8 micro-inches—the best finish was 1·4 for mechanically lapped, super-finished and metallographic finish. Briefly, these three methods of preparation, together with those of sanding and honing, all showed a layer of cold-worked ferrite of varying depth above the normal austenitic structure, the best being metallographic polish, followed by super-finishing and mechanical lapping (apparently equal); the material which had been reduced cold to 50% reduction showed wholly cold-worked ferrite.

The most marked transitions were observed in the ground specimens. In the case of dry fine grinding, a film of distinguishable oxide is seen at the surface and underneath which extends an appreciable depth of deformed austenite, then a transition zone of lesser depth consisting of cold-worked ferrite with deformed austenite, followed by the usual zone of cold-worked ferrite and finally the basic austenitic structure. This preparation showed by far the greatest degree of working and variation in structure, the zone of all cold-worked ferrite being at a depth of approximately 0·001 cm. Wet grinding, of course, eliminates the temperature effect, which gives rise to the oxide film in the case of dry grinding, after which the various zones follow similarly to those recorded for the latter treatment, but with a lesser depth of deformed austenite. It should be mentioned in the case of the ground specimen that the existence of a weak pattern of oxide was only obtained when the electron beam was reflected perpendicular to the directional scratches and, following this, more than 2,000—3,000Å had to be removed before a pattern could be obtained in order to give a readily identifiable structure.

In the metallographic studies the materials used were β-brass, β-bronze and 14% manganese steel, since the two former are noticeably sensible to hot-working and all show transformations on cold-working. Also, at the magnifications required for the examination of such fine layers and depths from the surface, it was not possible to show by etching the necessary degrees of difference between the ferrite and austenite of 18/8 (for purposes of comparison). Metallographic preparation was by alternate polishing and etching of transverse sections cut through the prepared surface, which had previously been protected by means of a layer of electro-deposited nickel. In each case, it was possible to discern at × 2,300 a transformed layer, due to grinding of the top face, extending down to depths of about 1×10^{-3} cm such layers appearing fine-grained and distorted (when resolvable) in comparison with the relatively coarse-grained structure of the basis material. Immediately below this layer, each of the three alloys mentioned showed a martensitic structure due to cold-work and extending to depths of at least 1×10^{-4} cm. Metallographic evidence of the temperature effect due to grinding is shown by the presence of wholly α-phase in the β-brass (only discernible visually), while, in the case of brass and bronze, numerous small cracks are formed by grinding—they are not visible when the surface is prepared by lapping. In the case of various steels, such fine cracks are attributed more often to the existence of retained austenite which, when severely worked (*e.g.* by grinding), may transform—sometimes, even when the deformation is cold. Such transformation will tend to produce surface cracks, so that, in such instances, the fault lies in heat-treatment practice rather than with the technique of grinding.

Corrosion tests were by atmospheric exposure, salt-spray and hot salt water immersion on low-carbon steel, hardened alloy-tool steel and 18/8 stainless. Wulff apparently considers the results on the last material to be of some importance. The

higher initial and final rates of corrosion of the rough ground surfaces were attributed to the presence of surface 'fuzz' and distorted metal and also, perhaps, to entrapped impurities and minute surface cracks—the latter were also observed in severely cold-rolled material, with increased corrosion rate. The effect of such cracks can be removed by deep pickling. A certain degree of cold-work (5% by cold-rolling) and also polishing tend to make the surface more resistant than does super-finishing alone. This effect has been commented upon previously[52] and is generally considered to be due to uniformity of the surface, *i e* over which only small differences in potential could exist.

The major comment on Wulff's corrosion results, however, applies to the use of 'loss in weight' as a criterion of the surface resistance. When steels of the 18 8 type undergo the pitting form of corrosion, attack is usually at a few isolated points, so that it must be questionable whether loss in weight can be significant. Indeed, series of such tests, in which the greatest single loss was 1·4 mg/cm², can hardly be seriously considered from the aspect of weight loss, and especially when the greater part of the total loss will be from only a few points. At the same time, it must be admitted that the sequence of weight loss results recorded by Wulff for 18 8 stainless steel is approximately the same as that given by means of the diffraction method and by metallographic examination.

To summarize Wulff's results, fine-grained and severely distorted austenite to a depth of $6{\cdot}3 \times 10^{-4}$ cm was shown in the case of fine grinding. For this material to have remained face-centred means that during deformation the lower boundary must have been at about 200 C. From considerations of heat flow, it has been calculated that the surface temperature of the top layer of atoms will be between about 700 C and the melting point of the metal. Although such flash temperatures may exist, they will never reach depths of $6{\cdot}3 \times 10^{-4}$ cm, and certainly not at the same time as the effects of mechanical deformation. The work must move to another point of contact before the thermal flash can reach this depth. Auxiliary rolling experiments led to the belief that the presence of deformed austenite can be attributed to the heat engendered during the severe and rapid plastic deformation accompanying the grinding process. At the same time, it is not considered that the flash temperature results of Bowden and Leben[53] are vitiated, since they are well confirmed by the depth of oxide film formed at the surface.

Apart from the criticism made above, the corrosion results are of value in attributing the higher initial and final rates of corrosion of the rough ground surface to the presence of surface 'fuzz' and distorted metal and, possibly, also to the presence of minute surface cracks.

Wallace[54] has also appreciated the significance of smear metal and the necessity for its removal if optimum surface finish is to be obtained. He visualizes three metallurgical conditions existing when the metal surface has been prepared by turning, grinding or honing—first, the fragmented crystalline metal which has been ruptured from the main crystalline body, but which retains its crystalline structure; second, the so-called amorphous or smear metal which holds the fragmented crystals together; and, third, the basis metal, isolated points of which extend into the defective smear surface, which, to some extent, fills in voids between the free crystalline and the base crystalline metal. Any subsequent operation, such as burnishing, crushes the free fragmented grains and the projecting points of basis metal into the disturbed surface structure, so levelling the metal surface, but only by the formation of a smear metal surface.

The requirements for the production of a true, fine finish are, therefore, twofold. Firstly, the geometrical requirement—the removal of previous surface roughness, scratches, etc, while the second, the metallurgical requirement, involves the removal of the defective surface of smear metal to expose the undisturbed crystalline basis metal. The only manner in which this latter can be achieved is by the clean cutting of the basis crystal grains and without the development of any real degree of plastic flow.

The removal of 'smear metal'

The obvious solution to the problem of smear metal is its removal by chemical etching, but this method would not generally produce the necessary degree of surface finish, and certainly could not be used on a production basis for working to fine limits. Certain electrolytic chemical polishing treatments are finding increasing use for the production of components, but even these could not in general be regarded as replacement for finish machining. The surface disturbance, both of contour and metallographic structure, however, brought about more particularly by dry grinding, constituted a serious drawback and the development of Superfinishing, notably in the U S A, was an outstanding contribution to the removal of smear metal by productive means. Wallace[54] has supplied metallographic evidence to show the clean cutting resulting from a super-finished surface with no real disturbance of the structure by plastic flow.

The operational advantages of Superfinishing point readily to the superior metallurgical condition of the finished metal surface. These advantages are principally: (i) Low speeds (3—50 ft/min) in comparison with those for finish grinding; (ii) correspondingly lower abrasive pressures; (iii)

superior abrasive action—short strokes at great rapidity and random direction of the abrasive stones —to give a scrubbing and abrading action which removes the defective metal layer from the surface (in comparison with the single direction, heat-producing action of grinding and honing, necessitating high pressures and speeds and so producing the fragmented layer of smear metal); (iv) no coolant is required, since no real degree of heat is produced. The only requirement is a light oil of suitable viscosity for lubrication purposes and to act as a vehicle for the minute particles abraded from the surface by the short stroke of the stone; (v) the production of a geometrically smooth surface having a truly crystalline surface with no disruption; (vi) although essentially a finishing process, Superfinishing can be adapted to roughing operations (for dimensional requirements) by the use of coarser abrasive and slightly increased pressure and speed to give a mass-produced quality of surface superior to that obtained by other methods, using much greater speeds. Even so, the Superfinishing dimensional operation should be followed by the Superfinishing finishing technique if the true crystalline surface is required.

Of the advantages given above, certain corollaries should be considered in relation to items (iii) and (v). The frictional resistance to chip flow is maintained at a low value by replenishment of the film between tool and chip, the process involving the use of frequent (or, preferably, continuous) changes in the direction of rotation of the abrasive particles relative to the work and thus avoiding long continued contact of freshly ruptured metal with a given point on the abrasive grain (*i e* the sides of the scratches produced by the minute abrasive grains are relatively smooth and free from transverse irregularities).[28] Again, the minute abrasive points do not accumulate relatively great volumes of metal ahead of the abrasive grain with the production of deep scratches, as in grinding and honing.

Briefly, the previous concept that dimension and surface finish can be carried out simultaneously is false in that the surface obtained is geometrically defective in topography and metallurgically defective in physical structure. These conditions can be eliminated by Superfinishing, involving the use of low abrasive speed and pressure, multi-directional motion, bonded abrasive and suitable lubricant.

Effect of cold-work on surface finish

In the previously recorded equation of Ernst and Merchant,[28]

$$\mu = S/H + \tan \theta,$$

the efficacy of preventing the formation of the built-up-edge by decreasing S, the average shear strength, was clearly shown. It was further suggested that it should be possible under certain conditions to prevent its formation by sufficiently increasing H (the mean pressure hardness value for the softer of the two metals in contact), while leaving S unchanged. Thus, a bad built-up-edge was always formed when taking a dry cut, 0·003 inch deep, on annealed aluminium, with the cut preceded by a similar light cut. The surface obtained was very rough. But, when the surface was first cold-worked to an appreciable depth by taking a cut, 0·025 inch deep, scarcely any built-up-edge was formed during a 0·003-inch cut taken immediately afterwards and a relatively smooth surface was obtained.

That the cold-work produced in the surface layers of the work is a function of the tool angle has been shown in connection with the face-milling of low-carbon steel and of magnesium alloys.[55] It was concluded that negative radial rake angle cutters developed a greater degree of cold-working than did cutters with positive radial rake angles and that the depth of penetration was also greater. Little variation was observed in the thickness of the affected surface layer produced on magnesium alloys by cuts of different depths taken at the same feed. The free-cutting action of magnesium alloys, however, has been remarked upon[56] since it is possible to obtain excellent surface quality from ordinary turning operations. Indeed, surface finishes of 4—5 micro-inches have been obtained commercially in precision turning and facing operations, no finish grinding operation being necessary.

Actually, there are two characteristics of cold-working which largely determine its effect on surface finish.[42] If the case of mild or dead-mild steel is considered, slip occurs along the cleavage planes when the steel is hardened by cold-working, so that the material can be visualized as being composed essentially of layers of soft ferrite, separated by films of much greater strength at the slip planes. Such films support the soft ferrite layers and the effect is similar to that of lamellar pearlite (in a steel of higher carbon content) in breaking up the continuity of the ferrite, so that the ductility is reduced and the surface finish improved. As the thickness of the soft layers is increasingly reduced by further cold-working, the finish becomes progressively better, but, owing to further work-hardening, it may be necessary to reduce the feed and speed of the machining operation, since greater forces are required to cut the harder metal.

Another characteristic of steel which has been cold-worked for reasons of surface finish is the manner in which the material stretches prior to rupture, when compared with hot-rolled steel of the same composition. The manner of elongation development prior to rupture is quite different for the two conditions, as can be shown by tensile tests made on bars of the same stock before and after

cold-working. There is marked elongation on either side of the break in the case of the hot-rolled material, whereas practically all the elongation of the cold-drawn bar occurs in the first inch. This difference in elongation development is another reason for the improved finish obtained on cold-drawn, as compared with hot-rolled, bars, and particularly if the steel is of the low-strength, high-ductility type. When the chip is sheared by the cutting tool, the area beneath it which is affected by the shearing action is restricted, but, with hot-rolled material, on the other hand, the metal is stretched for some distance below the surface before rupture finally takes place and an inferior surface finish results.

Surface finish in grinding

Owing to the distinctive character of the grinding process, Tarasov[57] has used the term ' grindability ' to describe machinability by the abrasive wheel and has introduced a further distinction between the ease with which stock is removed by grinding and the susceptibility of the material to cracking, the latter being referred to as ' grinding sensitivity.' Thus, two hardened steels may have the same grindability (the same resistance to a grinding wheel), but may differ greatly as regards grinding sensitivity. It is known that factors which markedly affect sensitivity do not affect grindability in any way, so that the adoption of a single description for the two unrelated phenomena would lead, of course, to confusion. Furthermore, a distinction between grindability and the ease with which a high degree of surface finish can be obtained is made by calling the latter ' finishability,' as suggested earlier by Ernst.[16] If such a distinction were not made and both characteristics embraced by the single term ' grindability,' it would be ambiguous to an extent that it would provide little or no reliable information concerning the response of a steel to grinding. Steels having a high rating from the standpoint of stock removal might have very possibly a low rating on the basis of surface finish.

References

(32) M. E. Merchant and N. Zlatin, *Trans Amer Soc Metals*, 1949, **XLI**, 647-672.
(33) E. Meyer, *Z V D I*, 1908, **LII**, 645.
(34) M. C. Shaw and P. A. Smith, *Machinist*, 1951, **XCV**, 1942-45.
(35) J. V. Emmons, *Trans A S S T*, 1922, **XXII**, 1100.
(36) N. E. Woldman, *J Amer Gear Mfctrs Assoc*, 1937.
(37) U S Air Force Machinability Rept, Curtiss-Wright Corpn, Woodridge, N J, U S A, 1951, vol I.
(38) U S Air Force Machinability Rept., *Ibid*, vol III, 1954.
(39) F. Wever, H.-J. Wiester, W. Strassburg, H. Opitz and K.-H. Frolich, *Arch f d Eisenhuttenw*, June, 1956, **XXVII**, 381-400.
(40) H. B. Knowlton, *Amer Soc for Metals*, 1938, 35-76.
(41) (See) K. G. Lewis and W. Milne, *Machinery*, 1953, **LXXXIII**, 70.
(42) J. D. Armour, ' Machining—theory and practice,' *Amer Soc for Metals*, 1950, 123-168.
(43) L. B. Pfeil and D. G. Jones, *J Iron St Inst*, 1933, **CXXVII**, 337-389.
(44) E. von Hambach, *Steel*, 1946, **CXIX**, 62-67; 116-118.
(45) L. F. Spencer, *Steel Processing*, 1949. **XXXV**, 31; 82.
(46) M. Field and E. E. Stansbury, *Trans Amer Soc Mech Engrs*, 1947, **LXIX**, 665-682.
(47) N. Zlatin, W. H. Friedlander and C. F. Walton, *Metalworking Prodn*, 1957, **CI** (28), 1201-1208.
(48) G. Beilby, ' Aggregation and flow of solids,' Macmillan, London, 1921.
(49) W. L. Bragg, *Proc Phys Soc*, 1940, **LII**, 105.
(50) J. Wulff, ' Friction and surface finish,' *Proc Spec Summer Conf, M I T*, June, 1940, 13-21.
(51) J. T. Burwell and J. Wulff, *Trans A I M M E*, 1939, **CXXXV**, 486.
(52) K. G. Lewis, (see) paper by T. P. Hoar and U. R. Evans, *J Iron St Inst*, 1932, **CXXVI**, 379.
(53) F. P. Bowden and L. Leben, *Proc Roy Soc*, 1939, **CLXIX**, 371.
(54) D. A. Wallace, ' The preparation of smooth surfaces,' *Proc Spec Summer Conf, M I T*, June, 1940, 22-43.
(55) F. Zankl, A. G. Barkow and A. O. Schmidt, *Trans Amer Soc Mech Engrs*, 1947, **LXIX**, 307-318.
(56) ' Manual on Cutting of Metals,' *Amer Soc Mech Engrs*, 2nd edn, 1952, 222.
(57) L. P. Tarasov, ' Machining—theory and practice,' *Amer Soc for Metals*, 1950, 409-464.

Uranium in Britain

concluded from page 376

specimens are received they are examined first by a specially constructed Geiger-counter which gives a rough indication of whether or not the material is abnormally radioactive. If the latter, representative portions of the specimens are crushed for accurate assay by radiometric techniques and the content of uranium or thorium estimated. Sections from the specimens are then cut by diamond saw and mounted for examination under the microscope. The sections of relatively transparent minerals are mounted on glass slides and rubbed down till they are about a thousandth of an inch thick; those of the more opaque species are examined by reflected light after polishing. Usually the minerals comprising the specimen can be identified in this way, but it may be necessary to remove minute fragments of any undetermined mineral for examination by X-ray diffraction. The photographs obtained by this latter technique are characteristic of the particular mineral species. When radioactive minerals are exposed on special emulsions, similar to those used on photograph plates, they produce an image or autoradiograph on development. Use is made of this phenomenon in the location of radioactive mineral grains and in their identification. Associated non-radioactive minerals in the specimens must also be identified, as the nature of these to a large extent dictates the technique that may have to be employed later in extracting the uranium or thorium.

The end-product of such an investigation is a report on each specimen or group of specimens submitted. This gives details of the uranium or thorium content and the nature of the minerals contributing to the radioactivity, with their grain size, and distribution in relation to the associated non-radioactive minerals. Attention is also paid in such reports to specific problems, such as the bearing of the mineralogical observations on difficulties that may be encountered in treating material of ore grade.

NADFS Spring lectures 1958

No 1

Forging-quality steels

Every year the National Association of Drop Forgers and Stampers organizes a series of educational lectures, designed primarily for the younger members of the industry, each lecture being followed by a discussion. It is felt that a summary of the more important points made by the various lecturers may be of interest to readers of METAL TREATMENT *and synopses of each lecture will appear in subsequent issues. The 1958 series began on April 22 when Mr W. Ash, F I M, chief works metallurgist of Steel Peech & Tozer, branch of United Steel Companies Ltd, spoke on some of the problems facing the steelmaker who undertook the production of forging-quality steels*

AFTER BRIEFLY OUTLINING the raw materials basis for the production of pig-iron used in the open-hearth process of steel-making which was responsible for 90% of the steel made in this country, the lecturer went on to describe the general procedure of working a typical basic open-hearth furnace, charge consisting of about 40% pig-iron analysing in %: C, 3·5—4·0; Si, 0·7; P, 1·5; Mn, 0·8 and 60% scrap. Having melted the charge, a sample was taken for the chemical laboratory to make a quick analysis. The aim was to melt out with 0·30—0·40% C above that actually required so as to allow the charge to 'boil.' This got rid of dissolved gases and enabled the temperature of the metal to be raised and thorough mixing to take place.

The refining process was fundamentally quite simple. On melting, the percentage composition of a typical charge could be: C, 0·60; S, 0·07; P, 0·4. The carbon had to be brought down to specification, normal practice being to catch it so that little or no recarburization took place. Sulphur and phosphorus had to be removed usually to below 0·05% or even less. At melt, an estimate of 'tramp' elements was made with the Quantometer, an instrument which measured the elements almost simultaneously by electronic means, thus effecting tremendous saving of time over chemical analysis. Percentages of nickel, chrome, molybdenum, tin and copper contents were obtained in a few moments of the sample being received. Occasionally there were excessive amounts of one or more of these elements which called for rapid action on the part of the operator, if necessary changing the specification of the final steel made.

The temperature of the steel was important, about 100°C of superheat over the complete melting point being necessary to enable steel to be tapped into relatively cool ladles and cast cleanly into ingot moulds.

Casting ingots

During casting, samples were taken for the 'pit' analysis which was accepted as the official cast analysis. Sometimes as many as six samples were taken during teeming to cover slight variations which can take place during the time taken to cast. It was thus possible to withhold any portion of a cast outside the specification.

There were several methods of ingot making, each having advantages and disadvantages. The metal might be poured direct into the moulds, and scabbiness, shelliness and general surface imperfections dealt with later. However, in making steel for drop forgings it was difficult to remove entirely any gross surface imperfections, so care was taken in the casting pit to obtain an ingot as free as possible from surface blemishes on the product afterwards. Bottom pouring was the method used, the steel being fed into a central runner and distributed to several moulds simultaneously through channels in the base plates, each mould being filled from the bottom. By this method, splash and gross shelliness were entirely avoided and the casting speeds could be controlled, so reducing incidence of ingot cracks.

Segregation

Segregation of elements was a common feature of ingots, and little could be done about it. Steel was a mixture of various constituents, the lighter ones tending to float upwards in the solidifying metal. Therefore, in an ingot the bottom region tended to be low in carbon and phosphorus and the top tended to contain more of these elements. Similarly these elements tended to be high in the centre axis region of the ingot. Therefore, the product of an ingot could show differences in analysis depending from which part of the ingot it had come. In a typical instance pit analysis was 0·32% and the variation in the product extended from 0·27—0·35%. That kind of variation also represented efforts to make steel to a particular carbon content; the pit analysis could be up or down from the target aimed for by somewhat similar amounts, the

distribution in both cases being gaussian. With large heats it was not always possible to work to some of the close limits requested. Five points carbon limits were difficult for the steelmakers.

Methods of steelmaking were continually sought to give less surface defects. Experiments were being made with rimming steel, killed in the mould, which gave a very thin-skinned ingot with good surface properties, better than any silicon-killed steel. A steel with 0·2% C and below with 0·6% max could have its applications. Unfortunately its negligible silicon content did not conform to the usual drop-forging steel specifications which mostly were 0·05—0·35% Si.

Surface treatments

As it was virtually impossible to make ingots without surface imperfections, a request for a very special forging-quality steel might involve removing the surface of the ingot before rolling. In the case of mild steels that would mean cold scarfing carried out by hand with an oxy-acetylene torch. The merit of that method was that the operator could see any local imperfections and remove them. It was costly but very effective. Higher-carbon ingots and alloy ingots could be cleaned up by planing. About 5% ingot weight was lost by those methods and in addition the economic advantage was lost of supplying the hot ingot to the mill reheating furnace.

Hot scarfing could also be done in the mill with oxy-acetylene equipment which removed all the surface simultaneously at the bloom stage, but it was non-selective. It cleaned the surface in a general way but could not remove gross local imperfections. It was found, however, that the quality of the billet very much improved. The billets were first inspected on the hot bed, the necessary samples being taken for tests. At this stage it was usual to take a small piece of billet which was upended immediately under a small hammer, this giving inspectors a guide on surface quality. The next stage was inspection and dressing, and the standards were high for drop-forging quality. If the forging process demanded a better quality from the steel-maker such as upending quality, great care had to be taken at that stage. Usually billets were pickled first to remove scale and reveal surface defects. The latter had to be removed by means of chipping or surface grinding, which was expensive, but it was aimed at producing steel which would do a particular forging job.

Discussion

A visitor said he was pleased to see the scarfing process mentioned, but the lecturer did not seem to be of the opinion that it entirely removed seams. He asked if all drop-forging billets necessarily had to be deseamed by the gas-oxygen flame process.

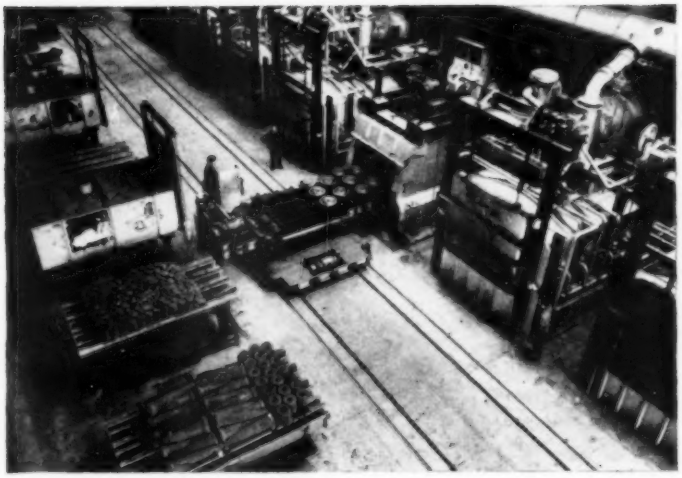
The lecturer, replying, said that his firm made a fully killed steel which was not generally seamy, but it did contain surface imperfections here and there. The normal method of putting the hot ingot into the mill and rolling it direct without losing its heat was an economical method. It went through the hot-scarfing machine which removed a uniform cut from the surface and removed many of the surface imperfections. But by virtue of it being a non-selective operation, the billets had to be examined and any remaining defects removed by hand. Cold deseaming of the ingot was more expensive, but it was intended to make the surface good by hand dressing before rolling. The difference between the two operations was that one was a selective hand-dressing operation and the other a non-selective machine-dressing operation.

Referring to carbon segregation, the lecturer said he did not think it was sufficiently well understood that the defect was unavoidable in sizeable ingots. It could be avoided only by making very small ingots which today could not be produced economically.

Replying to a question regarding the use of hot tops the lecturer said some praiseworthy attempts were currently being made to reduce their volume, a technique having been worked out using exothermic materials, instead of ordinary firebrick, to reduce hot-top volume from 12½ to between 6 and 7%. At present, however, the materials cost more than was saved, but doubtless the operation would soon be cheapened and made economical.

Asked whether increasing furnace capacity had added to the problems of meeting close carbon specifications, the lecturer said that it was not easy to make carbon steel to tight specifications from big furnaces. He could see the customer's point of view in his desire for a uniform product, but pointed out that, even if the official pit analysis was inside the specification, there was segregation inside ingots to contend with after that.

Finally the question was asked what was the difference in drop-forging quality and any other steel ? Why could not mechanical properties be guaranteed with tight carbon contents ? To this the lecturer replied that drop-forging quality steel was made and produced to withstand the operation of drop forging and produce a satisfactory article at the end of it. If the questioner cared to take re-rolling quality, particularly in balanced steel, he would find it so full of seams as to be useless. As a steel-maker he considered it unfair to be required to supply carbon steel, as rolled, to a tight specification and guarantee tensile properties as well.



Heat treatment at Darley Dale

General view of the new plant

THE COMMISSIONING of the new central heat-treatment plant at the Darley Dale works of the Firth-Derihon Stampings Ltd has led to a reduction of 50% of the labour force previously employed on heat treatment, and also a reduction of 75% in the maximum number of heat-treatment furnaces in operation.

When the Darly Dale works were built in about 1941-42, conditions then operating necessitated the installation of a coke-fired producer-gas plant to operate in conjunction with producer-gas-fired forge reheating and small batch-type heat-treatment furnaces. These operated satisfactorily up to 1956. At this time the need for greater accuracy of heat-treatment procedure to deal with the whole range of high-quality alloy and carbon steels, nickel-based and titanium alloys, together with increasing maintenance requirements of the gas-producer plant, brought about the decision to change over to the use of town's gas for all furnace firing and to modernize the furnace equipment.

The first stage in the modernization programme was the laying of a 12-mile-long, 15-in.-dia high-pressure town's gas main from Chesterfield via Matlock to the Darly Dale works, the installation of a new high-capacity town's gas meter and governor house, and extensive modification of the internal distribution gas main. Although the Darley Dale and Tinsley works had previously been responsible for the heat treatment of their own production it was decided to install a complete new heat-treatment plant at the Darley Dale works capable of handling the whole of the heat-treatment requirements of the company and to concentrate all heat treatment at these works.

The new plant which incorporates many advanced ideas was designed jointly with Gibbons Bros Ltd, Honeywell-Brown Ltd, Hartons Ltd, and members of the Brown-Firth Research Laboratory, and consists of three Gibbons dual-system town's gas-fired heat-treatment furnaces; two Gibbons town's gas-fired tempering furnaces; a Gibbons oil-quenching machine; a Gibbons-Van Marle turn-table charging machine; loading tables and special-type cooling tables; an instrument-control room; and a centralized waste-gas discharge system.

Furnace design

The furnaces are 11 ft long, 6½ ft wide and 3¼ ft high to spring line of arch in doorways. Furnace loads up to 5 tons weight are handled. The dual-system furnaces have normal operating temperature ranges of 200—750°C with forced recirculation, and 750—1,250°C without forced recirculation. The tempering furnaces have normal operating temperature ranges of 200—750°C with forced recirculation.

Furnace temperatures are electronically controlled by a fully automatic electro-pneumatic system, the Honeywell-Brown control instruments being housed in a centrally positioned air-conditioned instrument-control room. The tempering furnaces are two-zone controlled and the dual-system furnaces single-zone controlled. Temperature distribution throughout the furnaces is held to very fine limits and is indicated and recorded at any six points in each furnace.

All furnaces are fully instrumented and controlled to safeguard against failure for any reason. Compressed air supply for operation of the pneu-

matic control equipment is obtained from duplex air compressors and receiver units mounted on top of the centrally sited instrument-control room.

The oil-quenching machine is of very modern design, being of the fully-enclosed type with automatic door operation. Automatic lowering and lifting of the load with variable-controlled oscillation of the load during the quench period is also incorporated. This ensures the optimum oil flow conditions during the quenching cycle.

For cooling the oil in the quench machine, the oil is drawn from the top of the tank, passed through a water-cooled oil cooler and returned to the tank *via* distribution ducts in the tank base. The oil cooler is capable of dealing with 27,000 gal/h of oil, using 12,000 gal/h of water. Oil temperature is shown by an indicator on the discharge pipes from the oil tank.

ABOVE *A conveyancer 6,000 lb. capacity diesel fork-lift truck moving a stillaged load of forgings*

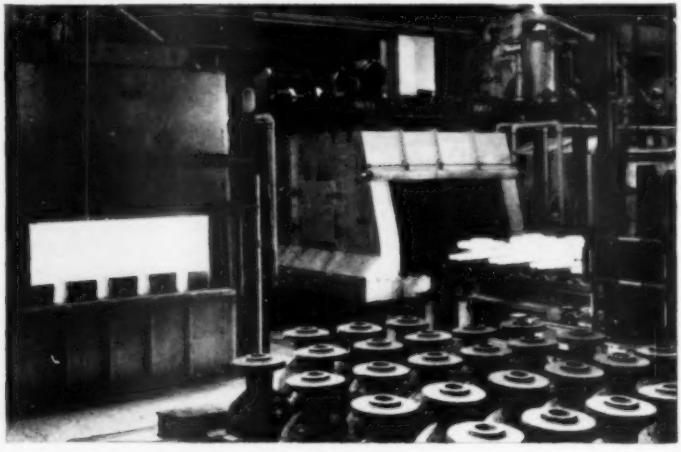
Materials handling

The charging machine used in conjunction with the loading tables, furnaces and oil-quench machine is an all-electric, four-arm turntable design arranged for 5-ton loads. Four motors are used for hoisting, lowering, charging and discharging, traversing and rotation. Power is supplied to the charging machine *via* a specially designed motorized cable-drum unit, mounted on the charging machine, the feed cable being laid down in a small duct below floor level.

The general layout has been designed to handle large and small batch production efficiently and to eliminate manual handling, as the plant has to deal with a wide range of forgings varying in weight from a few ounces up to about 800 lb.

All incoming materials are received into the reception bay in stillaged form, diesel-engine fork-lift trucks and electric battery-operated stillage trucks being used for the movement of all stillaged loads into the storage area, between the storage area and the loading tables, after treatment, and for the movement of stillaged loads to the adjacent inspection department.

In the main heat-treatment bay, electric overhead cranes are used for assembling the heavier forgings on the loading tables, etc. Dependent on the weight and section of the forgings to be treated they are loaded into special heat-resisting furnace trays or on to heat-resisting bearer-bars. After the load has been assembled on the loading table it operates as a unit load throughout all subsequent operations in the heat-treatment department.



RIGHT *Gas-turbine discs being transferred from a dual system furnace to the oil quench machine via the rotating charging machine*

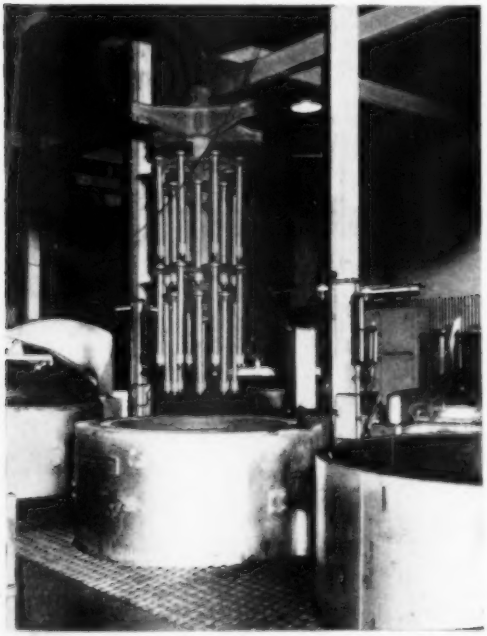
NEWS

Electric pit furnace installation

THE STANDARD MOTOR CO LTD is well known as the manufacturer of the Massey-Harris-Ferguson range of tractors. During manufacture, the axle shafts for this vehicle are subjected to a hardening and tempering treatment. Five electrically-heated pit furnaces and accompanying all-quench tanks were designed and supplied by G W B Furnaces Ltd to carry out the hardening part of the heat-treatment cycle. Where parts, such as these axle shafts, of relatively long and slender dimensions require to be heated at high temperatures, it is considered that the pit-type furnace, in which these components are suspended vertically, constitutes the best type of unit if distortion is to be kept to a minimum.

Thirty-two axle shafts, each weighing 37½ lb, comprise a furnace load and are carried in specially designed cast nickel-chromium jigs in two tiers of 16 shafts. The five furnaces are designed to produce an output of 4,000 hardened shafts per 120-hour week working on a 3¾-hour heating cycle, of which 1½ hours are required for bringing up to temperature, while for the remaining 2¼ hours the components are soaked at the required temperature. The furnaces themselves are capable of operating up to 1,050 C, although their normal working temperature is 950 C. At the time when the installation was visited, the shafts being treated were, in actual fact, being hardened at 840 C.

Each furnace has a 145 kW maximum electrical rating arranged in one automatically-controlled zone, governed by a Foster indicating controller with a 7-in. strip chart giving a continuous visual record of the heating cycle.



Jig loaded with 32 axle shafts being lowered into G W B pit furnace

Delta Star rating reduction is provided, which reduces the input to one-third of the maximum rating after thermal equilibrium has been obtained inside the furnace, and the soaking period then begins. This method of rating reduction is a desirable feature since it reduces undue wear and tear on the electrical contactors. The vestibule opening of the furnaces is 3 ft 2 in. dia, while the depth is 6 ft. The loaded jigs hang vertically, suspended from four heavy arms at the top of the ' spider ' in slots of heavy cast H R steel brackets which extend through the insulating bricks to the inside wall of the furnace casing. When the loaded jigs have been lowered into the furnace, the insulated lid is swung over into position, operating a limit switch which permits the heating current to pass to the elements which are of heavy nickel-chromium wire in coil form. These coils are arranged around the inside wall, supported on specially moulded open-type fire bricks. In addition to this safety limit switch, a further device, to protect the charge and the furnace, is fitted in the form of an excess temperature cut-out of the fusible type which melts at a pre-determined temperature and cuts off the current to the heating elements through a relay in the control panel.

During the hardening period a protective atmosphere is present inside the heating chamber to reduce scaling of the shafts to a minimum. At the end of the cycle, the shafts are lifted up and moved over by means of a hoist running on an overhead mono-rail, and plunged into the adjacent oil-filled quench tank. The oil from all the five quench tanks is circulated through a common cooler, situated outside the heat-treatment shop. After quenching, the shafts are then moved round to a washing and de-greasing machine before being transferred to the tempering furnace line for further treatment.

A new creep-resisting alloy

Henry Wiggin & Co Ltd announces the introduction of Nimonic 105, a further heat- and creep-resisting alloy in the Nimonic series. Nimonic 105 is a development of the nickel-chromium-cobalt-molybdenum alloy Nimonic 100 and shows a useful advance in high-temperature properties. It has greater resistance to creep at very high operating temperatures than Nimonic 100, the minimum life to rupture at 7 tons sq in. and 940 C (1,724 F) being 50 hours.

An important advantage of the new alloy is its improved resistance to a specific type of high-temperature corrosion sometimes experienced in aero and other gas turbines running at elevated gas temperatures. This corrosion occurs in certain conditions of contamination by solid or molten sulphates associated with the combustion process. The fuels used in this temperature range are high-grade distillates, such as aviation kerosene, which at lower temperatures have little or no corrosive effect. It will be appreciated that this form of high-temperature corrosion is quite different from the fuel-ash corrosion troubles met at much lower temperatures when certain types of boiler oils are burned in gas turbines.

Nimonic 105 has already been tested by the British aero-engine industry and is now in production.

Alloy	Stress tons sq in.	Temperature	Hours to rupture, minimum
Nimonic 95 ..	7	940 C	15
Nimonic 100 ..	7	940 C	30
Nimonic 105 ..	7	940 C	50

Mr John Penfold

Birlec Standard Furnace Division

Until recently, at Birlec Ltd, orders for standard furnaces were built by the Heating Division, which handled both large and small installations. The need was then felt for a separate division to handle solely this type of work and a new department, known as the Standard Furnace Division, has been formed under the management of John Penfold, previously Furnace Department manager of the Morgan Crucible Co. The instigation of the Standard Furnace Division has already been found to have considerably moderated costs and deliveries have been expedited.

Open days at Northern Aluminium Co's Banbury works

Visitors to Northern Aluminium Co's Banbury works last month saw the result of almost four years of continuous development. Although the installation of new equipment and the rearrangement and modernization of existing installations is not yet fully completed, within a few weeks' time the latest of the rolling mills will be at work.

Modernization has been in progress since 1955 without greatly interfering with production; it has been carried out step by step, and as each unit has been installed or renovated it has been brought into use.

First to undergo change was the Remelt Department. Here pig brought from Canada is remelted and quantities of other metals mixed with it to produce the Noral alloys which are then cast into ingots for rolling and cylindrical billets for extrusion. Coke-fired furnaces were converted to oil-firing and equipped with automatic charging gear, and the casting units have also been improved to produce ingots weighing a ton.

Visitors were able to see the Sheet Mill where the greatest changes have taken place. Interest was shown in the new scalping machine which skims roughnesses from the face of the ingots before rolling, and is capable of handling, automatically, pieces three times the size of those handled by the lathes it replaces.

Before rolling, the ingots are heated in a pit-type furnace of modern design big enough to hold 120 ingots, each weighing a ton, and equipped with an all-aluminium crane that enables the work of charging and unloading to be done by one man. This furnace serves the new hot mill, which was installed this year, with rolls 7 ft wide. One device to increase the efficiency of the new mill is a roller conveyor linking it with the preheat furnace, the flow of ingots to the mill being regulated by a ' magic eye.'

After reduction in the mill the resulting slabs are sheared and stacked by a special machine. The stack of slabs, which may be up to 80 ft long, is then moved sideways by an ingenious conveyor to a place where an overhead crane will pick them up for the next operation. This is the next phase of rolling and will be carried out on a new mill, 7 ft wide, which is now nearing completion. Replacing a pair of smaller mills, it will roll the slab in the flat, passing it backwards and forwards between the rolls, and when the requisite thickness has been obtained, ejecting it on to a 450-ft-long run-out table. At the end of this table it will be either coiled or cut up. The coil will then pass forward for finish-rolling.

Wild-Barfield N R C vacuum furnaces for Atomic Energy Authority

Wild-Barfield Electric Furnaces Ltd have received an order from the Atomic Energy Authority, Risley, for two 100-lb arc-melting vacuum furnaces of the cold-mould type.

The furnaces will be used for consumable and non-consumable melting. Each equipment has its own pumping system, but a common power supply is arranged, there being three rectifiers. Output is such that a 4-in. ingot can be melted in each furnace simultaneously with a 50% reserve of power.

British scientific films in Moscow

The 12th Congress of the International Scientific Film Association is being held in Moscow this month. Each year the Congress is held in a different country from among the 27 member countries of I S F A, and the Moscow meeting is notable as being the first international popular science film festival to be held in the Soviet capital. Among the films to be shown is a 28-minute film—' Forming of Metals '—by the Shell Petroleum Co Ltd.

Stainless steel compressor blades

Close-limit forging of compressor blades for jet engines has been carried out with the aid of the ' dag ' dispersions manufactured by Acheson Colloids Ltd.

One organization uses ' dag ' Dispersion 2404 (colloidal graphite in white spirit) in concentrated form on large blades (6—12 in. long) and diluted with five parts white spirit in smaller blades. The standard method of application is by means of a spray gun on to the dies between each forging. Advantages claimed are good metal flow, improved surface finish and longer die life.

Preliminary experiments carried out to evaluate the possible use of colloidal molybdenum disulphide in the same application suggest that good die finish can be obtained with MoS_2.

Four stages of forging stainless steel compressor blades

PEOPLE

Dr Joseph Herbert Watson, CBE, MC, PhD, ARSM, BSc, who is Chemist and Assayer of the Royal Mint, has been a Member of the Council of the Institution of Mining and Metallurgy since 1949, serving as a Vice-President from 1954 to 1957. He joined the Institution as a Student in 1919, became an Associate Member in 1924, and a full Member in 1941. He has now been named as president-elect of the Institution.

After leaving Malvern, Dr Watson entered the Royal School of Mines in 1914, but war service soon interrupted his course. He was commissioned in the 7th Division Signal Company, Royal Engineers, and served in France 1915-17 and in Italy 1917-19, being mentioned in despatches and awarded the Military Cross in 1916. Returning to the Royal School of Mines, Dr Watson obtained the Associateship and B Sc degree in Metallurgy in 1921. He was awarded the Ph D degree at London in 1933.

After a few months with Welsh Mines Corporation, Dr Watson joined the Royal Mint in February 1922, and has held the positions of assistant assayer, works metallurgist, senior technical officer, assayer, and finally Chemist and Assayer. He has worked in many branches of metallurgical research, assaying, melting and rolling, and has run the large foundry dealing with the melting and casting of precious and non-ferrous metal alloys, in addition to advisory work on metallurgical problems and in the administration of the Royal Mint.

The results of his investigations have been published, jointly with Sir Thomas Rose and with Dr S. W. Smith, and also under his own name, in the *Journal of the Institute of Metals*, of which he is a Member, and of whose London Local Section he was chairman from 1946 to 1948, serving during that period also as a Member of Council of the Institute. He is also a Fellow of the Institution of Metallurgists.

Dr Watson was awarded the M B E in 1945 and the C B E in 1957. Dr Watson was unanimously elected president of the Institution for the session 1959-60 in succession to Mr J. B. Dennison, and will take office in May next year.

William M. Frames, of Johannesburg, formerly chairman of Rand Mines Ltd, has been named chairman of the International Nickel Co S A (Pty) Ltd, South African subsidiary of the International Nickel Co of Canada Ltd.

Mr Frames will be chief executive officer of the International Nickel Co S A (Pty) Ltd, which is engaged in mineral exploration and investment. The company is opening new offices in the Palace Buildings, Pritchard Street, Johannesburg.

Mr H. Morley, deputy general works manager of Samuel Fox & Co Ltd, a subsidiary of the United Steel Cos Ltd., has become general works manager of the company in succession to **Mr J. D. Joy.** As already announced, Mr Joy has been appointed director and general works manager of Appleby-Frodingham Steel Co. with a view to becoming deputy general manager on January 1 next.

Mr P. S. Beale has been appointed a director of the British Oxygen Co Ltd. Mr Beale was formerly Chief Cashier, Bank of England, and recently general manager of the industrial credit and investment Corporation of India Ltd, Bombay.

The Incandescent Heat Co Ltd announces the formation of a Gas Atmospheres Division. The division is headed by **Mr I. L. S. Golding** and will be responsible for the design, development and sales promotion of gas and controlled atmosphere generators and gas dryers.

Mr N. S. Billington, M Sc, M I H V E, who has been Head of the National College for Heating, Ventilating, Refrigeration and Fan Engineering since February 1950, has resigned to take up the appointment of director of the Heating and Ventilating Research Council. As successor to Mr Billington the governors of the National College have appointed **Dr David R. Scott,** at present a senior lecturer on the staff of the Royal College of Science and Technology, Glasgow.

Dr Scott, who is a graduate of the Universities of London and of Nottingham, has had a wide research and teaching experience; in particular, he has specialized in the field of ventilation, and amongst other achievements is responsible for the design of a network calculator, whereby the distribution of air in networks may rapidly be determined.

Mr H. W. A. Waring, who is to be responsible for the general direction of the central advisory service set up by the Guest Keen & Nettlefolds group of companies to take full advantage of the opportunities offered by the European Free Trade Area for British iron, steel, and engineering exports, has been managing director of Brymbo Steel Works Ltd, and a director of the Guest Keen Iron & Steel Co Ltd, and of John Lysaght's Scunthorpe Works Ltd, since 1956. Educated at Christ's Hospital, Mr Waring qualified as a chartered accountant in 1929. From then until the outbreak of war in 1939 he spent many years in this capacity in northern Europe.

Mr H. W. A. Waring

During the war he was attached to the British Embassy in Stockholm, where he worked on blockade-running operations of steel and strategic materials from Sweden to the U K. After the war he joined the Control Commission for Germany.

In 1947 Mr Waring left the Control Commission and was with the Guest Keen Baldwins Iron & Steel Co Ltd until 1951, when he joined the United Nations Economic Commission for Europe and became head of the industry division responsible for the international committees on iron and steel, coal, electrical power, etc.

The new advisory service, the G K N Group Export Services Organization, will operate from Shell-Mex House, Strand, London, W C 2, and will co-ordinate activities, such as market research, in the export field.

EVENTS

Cranes and their drivers
Steelworks cranes will be the subject of the 37th meeting of the Iron and Steel Engineers' Group of the Iron and Steel Institute, which is being held in Chester, October 14 to 16.

The first day's discussions will centre round the crane in relation to the man who operates it. The papers to be discussed will include a report on crane safety in the iron and steel industry, prepared by the Accident Prevention Committee of the British Iron and Steel Federation, two papers on the ergonomic aspects of crane design from the British Iron and Steel Research Association, and two more general papers, one on engineering psychology, and the other on human temperature regulation, from the Medical Research Council.

In the second technical session, the steelworks crane will be discussed from an engineering viewpoint. The papers to be presented, both from B I S R A, will be devoted to structural design of cranes and to a plain frame method of analysis for lattice girders.

In addition to the two technical meetings, there will be an all-day visit (October 15) to the Irlam works of the Lancashire Steel Manufacturing Co Ltd, followed by a dinner in Chester by invitation of the company.

Further details may be obtained from the Secretary, the Iron and Steel Institute, 4 Grosvenor Gardens, London, S W 1.

Fifth international discussion on heat treating
The fifth international discussion on heat treating, organized by Institut für Härterei-Technik, Bremen-St -Magnus, Germany, will be held on October 15 in Wiesbaden. The general theme of the main session will be ' Heat treatment, residual stresses, service properties, especially resistance against fatigue.'

Part of the afternoon session will deal with the safety problem in heat treating under controlled atmospheres. Official languages will be English, French and German.

Practical uses of nickel
A series of four-day exhibitions devoted to the practical uses of nickel and its alloys are to be held in Newcastle, Leeds and Belfast by Henry Wiggin & Co Ltd. The first will be at the Royal Station Hotel, Newcastle upon Tyne, September 23-26; the second at the Metropole, Leeds, October 14-17; and the final one in this series will be from October 28-31 at the Grand Central Hotel, Belfast.

Running concurrently with each exhibition will be a series of lectures and films demonstrating the practical uses of Wiggin alloys in high-temperature work, and in chemical and electrical engineering, and others will feature welding techniques.

Tickets for each exhibition are available from the local area office of Henry Wiggin & Co Ltd, or direct from the head office at Wiggin Street, Birmingham, 16.

NEW COURSES

College of Technology, Birmingham
The Department of Metallurgy, College of Technology, Gosta Green, Birmingham, proposes to offer two post-graduate courses during the autumn term this year. These are (1) the metallurgy of nuclear-power materials and (2) spectrographic and chemico-physical analytical techniques for metallic materials.

The course on nuclear-power materials is intended for technical staff engaged in research and development on nuclear reactors, and for students proceeding to advanced metallurgy examinations. Ten lectures will be given on successive Tuesday evenings, commencing on October 7.

The course on spectrographic and chemico-physical analytical techniques is intended for metallurgists and chemists engaged in research and development work. The course will consist of 12 lectures held on successive Wednesday evenings, commencing on October 8.

The lectures will be illustrated by optical aids, together with laboratory equipment. The meetings will comprise a lecture, with demonstrations and discussions.

Full details of each programme, and application forms, can be obtained from the department. The fee for each course will be £2 2*s*.

Borough Polytechnic, London
The Borough Polytechnic, Borough Road, London, S E 1, has arranged a course of 10 lectures on refractories, their manufacture, properties and applications to be given by L. R. Barrett, M A, B Sc, M S, A R I C, M Inst F, F Inst Ceram, on Fridays at 7 p m, beginning on October 10 this year.

The course is organized to provide a detailed and up-to-date survey of refractories and the refractories industry.

Various aspects of fuel technology are dealt with in the following courses offered by the Borough Polytechnic.

Fuel technology, in preparation for the examinations in this subject by the City and Guilds of London Institute. This course may be taken either on a part-time day or an evening basis.

Fuel and combustion engineering, which is offered as an endorsement to the Higher National Certificate course in mechanical engineering. These classes are held on Monday evenings from 6 30-9.

Oil-burning technology. A course of lectures held on Friday afternoons from 2 30-4 30.

City and Guilds of London Institute
A new scheme under the heading ' engineering drawing ' has been introduced by the City and Guilds of London Institute and college courses will be commencing in the new session.

This has been designed to provide a good background qualification to enable the engineering apprentice to become a draughtsman, and it is intended that students with a variety of backgrounds should qualify for entry to the course, which is based on two years of part-time instruction. The course includes applied mechanics, mathematics and geometry, materials and processes, and there is throughout an emphasis on practical drawing.

Students who have followed National Certificate mechanical courses to S 3 level, or obtained Intermediate certificates in machine shop engineering, or appropriate Final certificates, may enter the course. There is a further provision for older students with a background of drawing office experience. No candidate, however, will be admitted to the examination who has not attended the specified course of instruction.

Full particulars of the above scheme are available on application to the Director of the Institute, Gresham College, Basinghall Street, London, E C 2, and enquiries should be marked ' B 5.'

The Institute has published details of the revision of the following subjects: (61) patternmaking, (62) foundry practice, (65) boilermaker's work, (66) sheet metal work, (74) welding and (176) fabrication of steelwork.

OBITUARY

Col J. W. Danielsen, D S O, D L, J P

Col J. W. Danielsen

We regret to report the death of Col Danielsen in a motor accident last month, on the Evesham-Cheltenham road.

John William Danielsen was born in Birmingham in 1875. He was of Danish descent (his father becoming a naturalized British subject), his family being connected with the firm of Rabone Petersen of Birmingham, well-known export merchants in the City. Col Danielsen was educated at Wolverhampton Grammar School. In 1911 he married Miss Lilian Sydenham. Col and Mrs Danielsen had four children, three sons and a daughter. Two of the sons were killed during the last war and Mrs Danielsen also died at that time. The surviving son, Mr R. W. N. Danielsen, is managing director to the Deritend Group of Companies and a member of the Governing Council of the National Association of Drop Forgers and Stampers; he was a prisoner of war in Germany for five years.

Col Danielsen had a most distinguished career and gave much of his time to public service. He was a past member of the Birmingham City Council and had been a City Magistrate since 1927. He joined the Territorial Force in 1908 and commanded a Signal Company, Royal Engineers, in World War I, during which he was mentioned five times in despatches and received the Distinguished Service Order. After the 1914-18 war he formed the 48th South Midland Divisional Signals, T A, which he commanded for some years. He became Deputy Chief Signal Officer, Southern Command, and was made an honorary colonel of 48th S M Divisional Signals in 1927, being gazetted full colonel on retirement. He was one of Her Majesty's Deputy Lieutenants for the County of Warwickshire.

In his business life Col Danielsen had been a director of the Deritend Co for 56 years and had been chairman and managing director since 1919, a position which he held until 1953. In that year the Deritend Stamping Co amalgamated with the Blackheath Stamping Co and South Wales Forgemasters, and he became chairman of the new group. This position he resigned at the end of February, 1958. During the half-century which Col Danielsen served with the Deritend Co he witnessed the growth, from very small beginnings, of the British drop-forging industry, his own company participating to the full in the general development, prosperity and importance of the industry.

Col Danielsen was president of the Birmingham Association of Mechanical Engineers in 1932 and 1933 and was chairman of the Midland Branch of the Institution of Mechanical Engineers in 1945 and 1946.

It was largely due to the foresight and inspiration of Col Danielsen that a British drop-forging trade association was organized in 1917. This developed, in 1945, into the present National Association of Drop Forgers and Stampers of which Col Danielsen was a past president and, until his death, a member of the Governing Council. 'The Colonel' was always an enthusiastic supporter of co-operation between competitors in industry and it was he who presented Grove Hill House as a permanent centre for co-operative action amongst drop forgers when the new constitution was set up in 1945.

Col Danielsen was a man of great energy, not only in business, but in many other directions as well. Although in his 83rd year, he was still playing tennis in 1957. He had only recently returned from a tour in Australia, New Zealand and the Far East. In Australia he acted as guest of honour at the first weekend convention of the new Australian Drop Forging Association, and made contact with many drop forgers in that country. He will be greatly missed by all who knew him in the industry.

Mr Lewis Lowe

Dudley Drop Forging Co Ltd announces the death of the founder of the company, **Mr Lewis Lowe,** who died at his home at Oldbury last month, at the age of 86.

Thermic boring process in a foundry

Metallic Extractors Ltd of Water Orton, Warwickshire, were recently called upon to remove a mass of raw copper which had solidified in a foundry owing to a breakdown in the furnace. Weighing about 85 tons, the copper could only be used when broken up into small segments and removed. It was believed to be the largest amount ever encountered in similar circumstances.

Initially, in an attempt to break the metal, a 2-ton steel ball was dropped on to it. This did not prove successful, however, since the roof clearance was only 12 ft and the ball skidded on the soft copper. Explosive charges were then set and this method resulted in a 6-ton piece being broken off. The laminations in the copper and the resilience of the metal, however, meant that the explosion was difficult to control and this method was also abandoned.

The firm sought the advice of British Oxygen Gases Ltd, and it was agreed that the thermic boring process should be used. A section of $\frac{3}{4}$-in. bore gas-barrel steel tubing was packed with $\frac{1}{4}$-in. dia mild-steel rods. Oxygen was then fed through the rods at the high pressure of between 100 and 150 lb/sq in. and the end of the packed lance was then ignited. The iron and oxygen reaction provided the degree of heat which was required to melt the copper.

Classified Advertisements

FIFTEEN WORDS for 7/6d. (minimum charge) and 4d. per word thereafter. Box number 2/6d., including postage of replies. Situations Wanted 2d. per word.

Replies addressed to Box Numbers are to be sent, clearly marked, to Metal Treatment and Drop Forging, John Adam House, John Adam Street, London, W.C.2.

SITUATIONS VACANT

A METALLURGIST OF AT LEAST L I M STANDARD is required to take control of a well-equipped laboratory and assist in interesting development work. Applicants should have a knowledge of the forging and heat-treatment characteristics of heat-resistant alloys, stainless, low-alloy and plain carbon steels. Pensions and profit-sharing schemes are in operation and canteen and recreational facilities are available.

Apply in writing, giving full particulars of age, qualifications and experience to the Secretary, Dudley Drop Forging Co Ltd, Holly Hall, Dudley Worcs.

TECHNICIAN WITH METALLURGICAL BACKGROUND for workshop control and development of new production processes. Write stating salary required to: Heat Treatment & Brazing Co. Ltd., Hersham Trading Estate, Molesey Road, Hersham, Surrey.

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AGENCY REQUIRED. Active sales representation in the Midlands for plant, machinery and raw materials. Top connections throughout. Drop forging and sheet metal pressing industries. Interested firms please contact Box A R 109, METAL TREATMENT AND DROP FORGING

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EFCO MUFFLE FURNACES, 18 kW, 1,200°C, 400 volts, three-phase, 50 cycles, complete with Electroflo temperature recorder and controller. Condition as new. Whitefield Machinery & Plant Ltd, Cobden Street, Salford 6. Tel : PEN 4746.

RADYNE HIGH-FREQUENCY HARDENING, brazing and soldering, 1½-kW unit. Unused. Wheway Optical, Barr Street, Birmingham 19. NOR 2291.

60-kW BAILEY TILTING RESISTANCE FURNACE, 415 volts. Complete with all control gear, meters, hydraulic pump and accumulator. Quick disposal. Johnson, Matthey & Co Ltd. Holborn 6989.

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INDUSTRIAL INSTRUMENT SERVICES Co, 74a Nursery Road, Birmingham 19 (NOR 2525), pyrometer instrument manufacturers and suppliers. Service and reconditioning of all types and makes of pyrometer instruments. Wide range of thermocouples, cables, and accessories, etc. Guaranteed work, prompt delivery.

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BOOKS

Electric furnaces

Edited by C. A. Otto. 14 chapters and index. Pp 248 + 157 illustrations. George Newnes Ltd, London, 1958. £1 15s.

THIS BOOK DESCRIBES in a very general way the application of a wide range of electric furnaces in various industries. The metallurgical aspects of melting and heat treatment have naturally received major attention though the requirements of the glass, vitreous enamelling, pottery and plastics industries are also brought in for consideration. The inclusion of other chapters on elementary electrical principles, pyrometry and refractory materials completes the contents.

Apart from three chapters by Mr Otto, the remaining 11 chapters have each been written by a different contributor. Some duplication of material results (*e g* the high-frequency furnace is dealt with in chapters 2 and 3), while the general standard of presentation also varies somewhat between chapters. The most informative chapters for a reader not already conversant with the subject-matter are those devoted to 'Metal-melting furnaces,' 'Electric heat in the glass industries' and 'Refractories and furnace linings.'

The book is profusely illustrated with photographs of electric furnace exteriors. While the choice of these photographs is generally good from the point of showing the clean, compact and enclosed design of modern electric furnaces, it is felt that a greater use of suitably annotated line or sectional drawings would have been of more benefit to the reader.

It is regrettable that apart from a limited bibliography appended to the chapter dealing with the glass industry, no other references are given to assist the more inquisitive reader. It is equally regrettable that the price of this popular style technical book is so high.

H. L.

Safety rules for employees in the drop-forging industry

Published by the National Association of Drop Forgers and Stampers, 16 pp, illustrated.

THIS SHORT BOOKLET was prepared by the Labour and Welfare Committee of the National Association of Drop Forgers and Stampers with the new entrant to the industry particularly in mind.

The aim was to set out in a very simple manner and in as short a space as possible, the normal risks which an employee in the industry might be expected to meet and how best accidents could be avoided.

The booklet presents this information in a clear and attractive manner and should be a most useful aid to the prevention of accidents in the industry if it receives the wide circulation it deserves.

Research associations

We have received the following research association annual reports:

Annual report for 1957 of the British Non-ferrous Metals Research Association

Annual report for 1957 of the British Iron and Steel Research Association

Annual report for 1958 of the British Steel Castings Research Association.

NEW NAMES AND ADDRESSES

The Industrial Furnaces and Engineers' Tools Divisions of Brayshaw Furnaces & Tools Ltd, Belle Vue Works, Manchester, 12, are now trading as separate companies under the names of Brayshaw Furnaces Ltd, and Brayshaw Tools Ltd.

The formation of separate companies takes place in the Diamond Jubilee Year of the foundation of the original company and has been adopted in view of the continuous development and expansion in both the furnace and tool trade which has taken place, particularly during recent years.

Mr F. I'Anson, sales manager of the Furnace Division, will continue to control home and export sales of Brayshaw Furances Ltd, whilst Mr W. Nunn, formerly export sales manager of the Tools Division, is appointed home and export sales manager of Brayshaw Tools Ltd.

The registered office of the two new companies will continue to be located at Belle Vue Works, Manchester, which have been considerably extended and re-equipped with a view to providing increased production capacity and modern office accommodation. A branch office for Brayshaw Furnaces Ltd has also been opened at 84 Blonk Street, Sheffield, 3.

To provide additional facilities for furnace repair and service, particularly in the Sheffield and surrounding territory, a Repair and Service Depot is now operating at Northfield Road, Rotherham. The depot will undertake all classes of furnace repair work, servicing and the conversion of existing plant to either gas or oil heating, and is fully equipped to carry out prompt and speedy repairs to all types of furnaces.

The British Association, after 67 years in Burlington House, has moved into a suite of offices in the house belonging to the Royal Society of Arts. The address of the association is now 18 Adam Street, Adelphi, London, W C 2 (TRAfalgar 5733/4).

The Scientific Film Association has moved to new offices in 3 Belgrave Square, S W 1. These premises have been made available by A S L I B and it is anticipated that this closer relationship will introduce the work of the Scientific Film Association to many who are concerned with documented information of all kinds.

The address of Aluminium (Canada) Ltd is now Aluminium Canada House, 30 Berkeley Square, London, W 1 (MAYfair 9721).

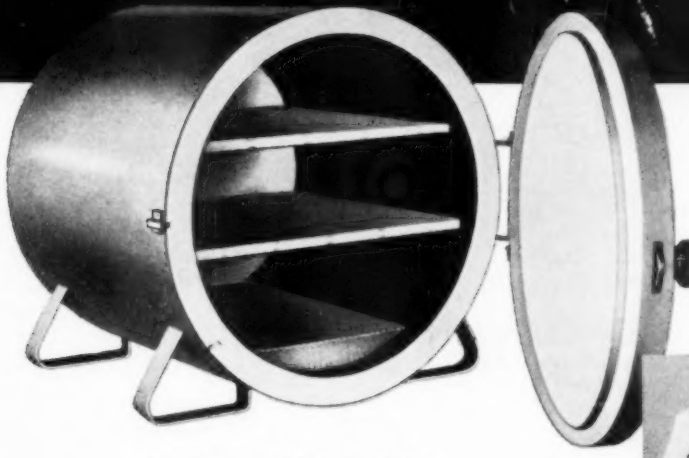
In future the Plastics Division of Metal & Plastic Compacts Ltd, Armoury Road, Birmingham 11, will be trading as the Motoplas Co Ltd ; and the Metals Division of M P C, of Montgomery Street, Birmingham 11, will be known as Metal & Plastic Components Ltd.

Metal & Plastic Compacts was set up by the B S A company in 1946 to investigate powder metallurgy and manipulation and moulding in the plastics field.

The executive offices of Kelvin & Hughes Ltd have moved to Empire Way, Wembley, Middlesex (Wembley 8888).

Samuel Fox & Co Ltd, a subsidiary of the United Steel Companies Ltd, announces that its research department will now be known as the metallurgical department. The change of name has been made to reflect more accurately the nature of the department's duties.

do you get faulty welds



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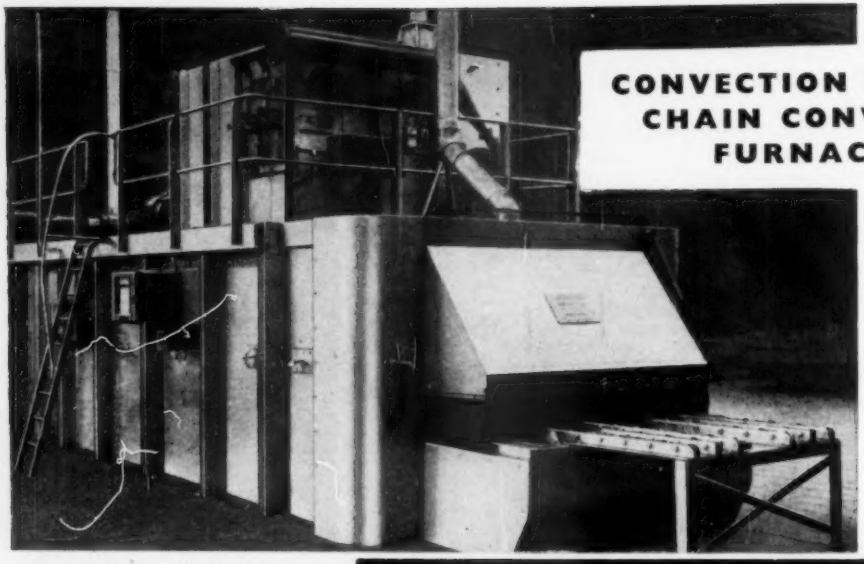

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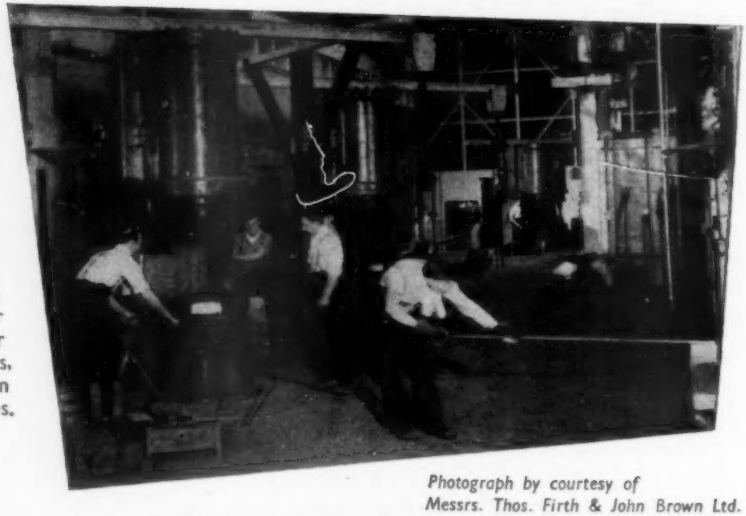

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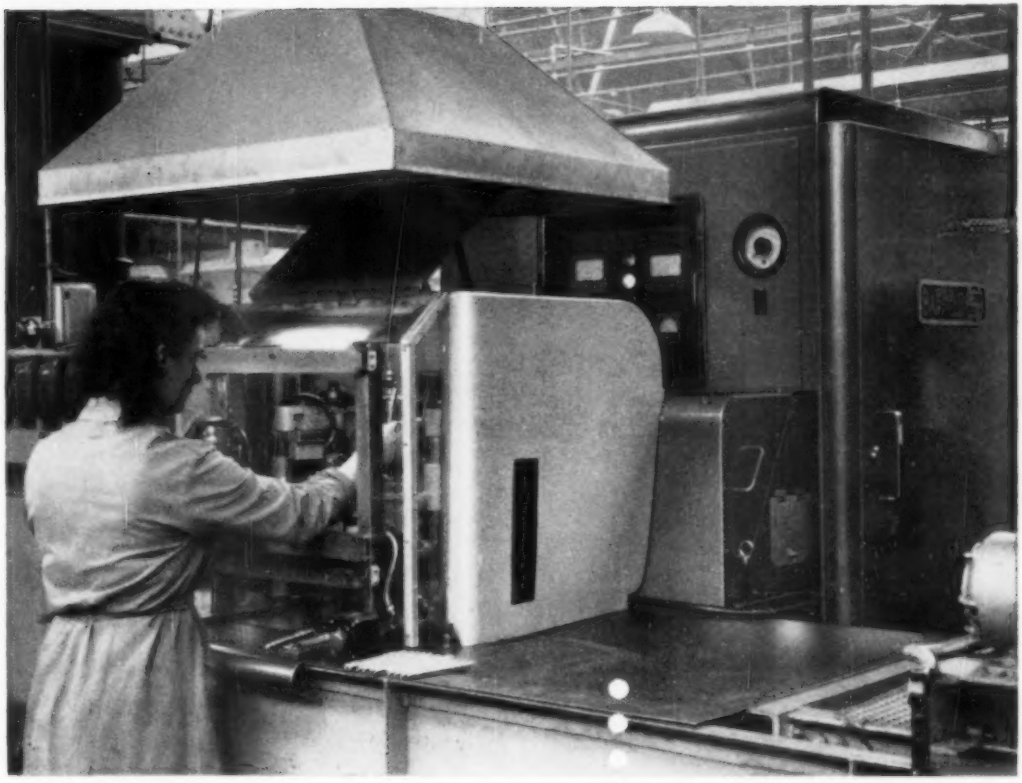

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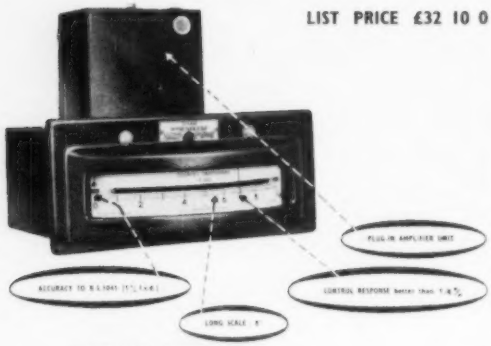

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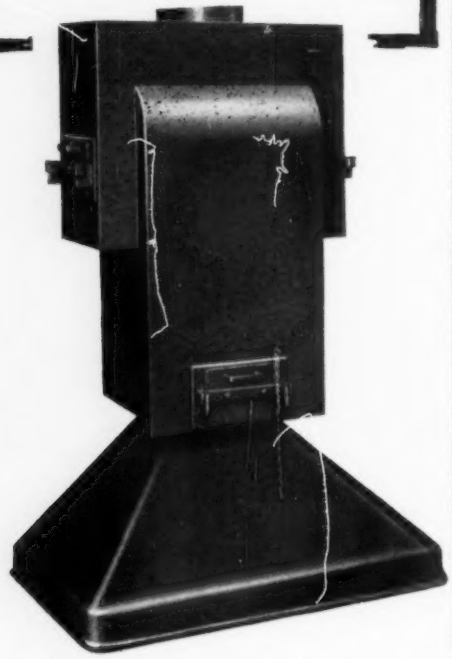

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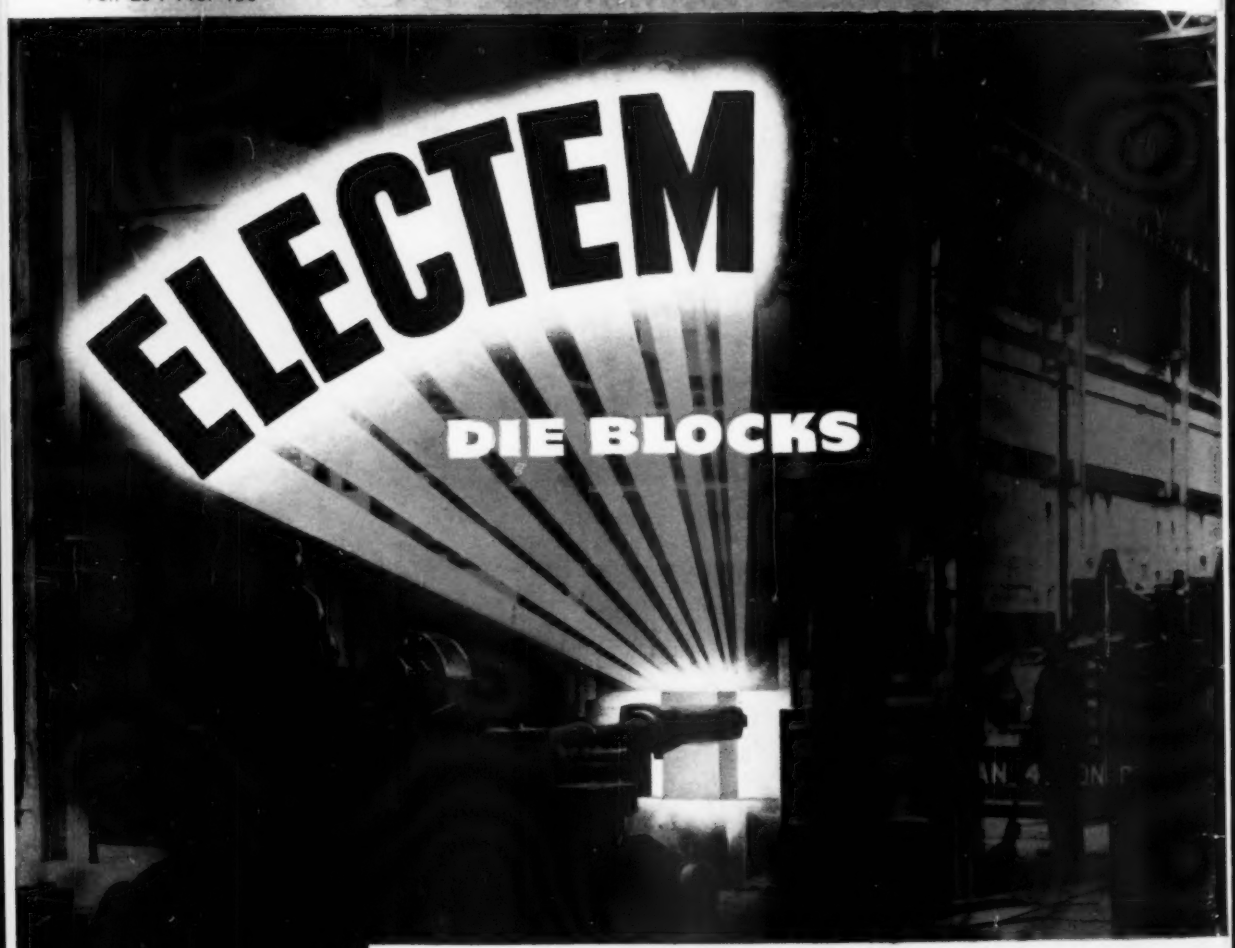

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